

CIVIL SPACE STATION

HEARING
BEFORE THE
SUBCOMMITTEE ON
SCIENCE, TECHNOLOGY, AND SPACE
OF THE
COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

NINETY-EIGHTH CONGRESS

FIRST SESSION

ON

CIVIL SPACE STATION

NOVEMBER 15, 1983

Serial No. 98-48

Printed for the use of the
Committee on Commerce, Science, and Transportation



U.S. GOVERNMENT PRINTING OFFICE

WASHINGTON : 1984

29-426 O

5261-13

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CIVIL SPACE STATION

TUESDAY, NOVEMBER 15, 1983

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9 a.m., in room SR-253, Russell Senate Office Building, Hon. Slade Gorton (chairman of the subcommittee) presiding.

Staff members assigned to this hearing: Peter Perkins, professional staff member; and Steven Flajser, minority professional staff member.

OPENING STATEMENT BY SENATOR GORTON

Senator GORTON. I am pleased to chair this hearing of the Subcommittee on Science, Technology, and Space as we examine in this, the 25th anniversary of NASA, the planning and direction of a national space station. This idea warrants our careful study not only in the context of the immediate decisions that must be made but also in the context of our more distant national space objectives.

It is fitting that we examine the concept of a permanent presence in space in this 25th anniversary of NASA. Since NASA's establishment 25 years ago, this Nation has achieved the preeminent world position in aeronautics and space. NASA has contributed immeasurably to advancing for all mankind our understanding of the planets and our universe. The agency's feats have been a special source of pride to Americans and has captured the imagination of the people the world over.

Now, however, we must think about NASA's future and how a permanent presence in space fits into our national goals, responsibilities, and opportunities. The President, in his National Space Policy of July 4, 1982, said that our civil space program should be conducted to preserve the U.S. leadership in critical aspects of space science, applications and technology. With this in mind, we should try to determine to what extent a permanent presence in space might satisfy our national space policy and our Nation's non-space objectives.

A national commitment to a permanent presence in space will require close scrutiny.

We must ask, How can a permanent presence in space serve our Nation and mankind now and in the more distant future? With each new space shuttle launch we are becoming more capable users of the space environment; now we should consider how we can

expand our present uses of space and how we can develop new capabilities that would have a unique applicability to a permanent presence in space.

Another question we must ask is, What alternatives exist for accomplishing our objectives in space, and what are the advantages and disadvantages of each? This question might be resolved, in part, by balancing budgetary considerations against the capabilities that may be gained or lost.

Budgetary considerations may lead us into the examination of cooperative participation in a space station development. For instance, in 2 weeks, on November 28, we are launching our ninth space shuttle mission which will carry spacelab, a joint NASA-European Space Agency research facility. Joint endeavors such as this may be worthwhile opportunities. Similarly, private sector financial and technological participation could demonstrate the true appeal and opportunity for space commercialization.

The level of Federal funding required for a space station development and the attendant budgetary impact are other factors that warrant our attention. Regardless of the type of permanent presence in space we may eventually have, we should insure that NASA's other programs receive a responsible level of funding for the sake of a balanced and ambitious space program.

After all of the technological and economic considerations have been examined in every possible permutation, we should look at a space station from a symbolic perspective. We must bear in mind what kind of leadership role we expect the United States to assume in space activities and in the world in general. Further, we should consider how a permanent presence in space would influence our Nation's prestige, character, and public perception.

The United States has always had a grand vision of the future of space—the Apollo lunar landings and the development of the space shuttle are examples of this grand vision we had years ago. Now we must determine how a space station fits into our grand vision for the next 10 or 20 years, and how it might best serve mankind and satisfy our quest for the unknown.

We look forward to examining this issue more closely today. We have a number of distinguished witnesses and it is my pleasure to welcome them here today.

Senator Heflin.

OPENING STATEMENT BY SENATOR HEFLIN

Senator HEFLIN. Thank you, Mr. Chairman.

In the United States we are now discussing whether we should move ahead with a space station development, and if so under what circumstances. The administration is currently reviewing this matter and we in Congress continue to gather information.

I am pleased that Senator Gorton, the chairman of the subcommittee, has called this hearing. I want to support him in every way I can to develop the information necessary for this committee and the Senate to act on the question of space stations.

Today's hearing will explore the uses to which a space station can be put and the alternate ways that we could satisfy those needs. We will also examine the impact of a space station develop-

ment on other NASA programs, as well as possible developments in the private sector.

Before we turn to our distinguished set of witnesses, however, I would like to share some of my own thinking on this subject. Two months ago I was asked to address an annual meeting of the Institute of Electrical and Electronic Engineers, the IEEE, on the question of space stations. Is it an idea whose time has come?

My response at that meeting, as well as last month in my statement on the Senate floor, was yes, space stations are an idea whose time has come. First of all, space stations are not just an idea. They are a reality; at least they are in the Soviet Union. Their space program continues to march along and they are developing a valuable capability in utilizing the Salyut space station, and as we know their station is a manned operation.

I am convinced that the public support of NASA and our space program has been one of the best investments this country has ever made. I believe that maintaining U.S. leadership in space science, technology and applications is critical to our national welfare. We must continue to push those frontiers of knowledge and capability.

We should not relinquish our technological preeminence to Russians, Europeans, Japanese, to anyone. Thus, I view a space station development program in that context, namely, it will help maintain U.S. leadership.

Yes, I agree with Mr. Beggs that it is our next logical step in space. My support for a space station development is clear, but with it comes a number of questions. It is only natural to ask such questions as, What are the alternate options and what will they cost? For example, how does an extended duration shuttle orbiter compare with an unmanned platform and a manned space station? We have asked the Congressional Office of Technology Assessment to do a study on these very questions, and I will be following the results of their study carefully.

Perhaps a more basic question I have is, Where does the space station fit into our overall goals in space? In my speech before the IEEE I emphasized the importance of a balanced space program. By balanced I mean we should not have a sophisticated space station capability without a healthy space science, applications, and technology program. A balanced space station development would include international and private sector involvement, and a balanced, cost effective space station program would consider short-term and long-term budget impacts.

Mr. Chairman, this subcommittee needs to explore these questions of balance and how a space station development will impact on our Nation's future. And we need to ask ourselves, where do we want to be with our space program in 1992, the 500th anniversary of Christopher Columbus' discovery of this great land. I hope to elaborate on this and other points during this hearing today and in the future.

Thank you.

Senator GORTON. Thank you, Senator.

Senator Tribble.

OPENING STATEMENT BY SENATOR TRIBLE

Senator TRIBLE. Thank you, Mr. Chairman.

Mr. Chairman, President Reagan at NASA's 25th anniversary celebration last month noted that we celebrate our potential as well as our accomplishments. NASA's accomplishments are legion. They are exceeded only, I believe, by NASA's potential.

Many here today believe that a manned space station will harness that potential, and I agree. A space station will allow us to harness the benefits of 25 years of dedication and hard work. We have gone to the Moon, we have explored the planets, we have parted the curtain of our solar system. Now let us turn to our next challenge, perhaps the biggest, to develop, deploy, man, and seize the benefits from an orbiting space station.

A space station will provide commercial opportunities, enhance our national defense, and allow us to build upon the scientific experiments of Skylab. When we have met this challenge, NASA's potential will have been transferred into gains for all of mankind.

As the President noted recently, Mr. Chairman, there is never a time when we can stop moving ahead and when we can stop dreaming.

Senator GORTON. Thank you very much.

Our first panel, representing Booz, Allen & Hamilton Inc., will include Mr. Wood and Mr. Stark. If they would come forward at this point we would be delighted to hear them.

I understand that, while both of you will be helpful to us in answering questions, only Mr. Wood has a prepared statement. Is that correct?

Mr. WOOD. Yes, that is correct.

Senator GORTON. You may proceed.

STATEMENT OF PETER W. WOOD, SENIOR VICE PRESIDENT, BOOZ, ALLEN & HAMILTON INC., ACCOMPANIED BY PETER STARK

Mr. WOOD. Good morning. Mr. Chairman, members of the Subcommittee on Science, Technology and Space, I am Peter Wood, senior vice president of Booz, Allen & Hamilton, and it is truly an honor to appear before this distinguished committee as you examine the concept and the early planning for a U.S. manned civil space station.

I think this is a key opportunity for the United States. It would provide a place for our people to do significant and often unique long-term work in orbit, and I think it is time to grab this brass ring.

I am greatly heartened by the opening statements of the gentlemen, because it tells me that you are clearly forward looking and you have identified some of the key reasons why we should very carefully consider this new initiative.

Booz, Allen is a leading professional services firm consulting in management and technology to government and industry worldwide. Our work has dealt with space and with NASA for nearly 20 years now. And personally, I have been with Booz, Allen for 16 years and most of my work in that time has dealt with defense and space.

Last year NASA reopened the question of a manned space station, having looked at it at the inception of the space transportation system efforts some years ago. And during this last year NASA has undertaken internal studies, but in addition has commissioned eight studies with aerospace contractors to look at some of the things that would become missions for the space station, would be the reasons for being, and have looked at some of the available technology and the kind of architecture that might apply.

During the course of that work, Booz, Allen was retained by one of those firms, McDonnell-Douglas Astronautics, to identify what the early commercial applications might be, what industry would do on orbit, and that involves some contact with a number of firms in the United States and a long list came out of our work and the work of the other contractors in those studies.

It was determined by NASA that it would be appropriate to continue that contact with industry, to try to find out what the thinking is and what the planning is that is going on that would result in work in space in the nineties. So we are still under direct contract to NASA on a modest effort which is termed "user development."

Our approach has been to meet with receptive firms and to open dialogues with them on the basis of seed application concepts. We find that in most cases these nonaerospace firms are not used to thinking in terms of what can be done in space and they welcome the opportunity to learn more about what the attributes of space, such as microgravity, can mean to the kinds of processes and products that they deal in.

In some cases, we get an answer that says: "We will think about it and maybe get back to you." In other cases, there comes to be a commitment to study carefully the opportunity that is represented, and in some instances this has led to approaches to NASA to enter into agreements so that early proof of concept of some of the ideas that they pick up or that they generate as a result of these stimulating dialogues will be tested in a microgravity environment, perhaps in a drop tube or in an aircraft or perhaps in a shuttle flight. And NASA has organized in such a way that these flights can be made available to companies who are in the development stage of a really promising effort.

A number of applications have generated from these dialogues we have been carrying on, and perhaps we can show some examples if you take the lights down, please. I just have three viewgraphs that I am going to use during the statement. I think they will help focus a little bit.

We are talking about such things as developing and growing crystals of a higher quality than can be done on Earth for communications and sensing equipment in a number of fields. On this chart what I have shown are summaries which are prepared in this way, because most of the relationships that we have with industry are proprietary at the early stages, and in most cases we have entered into written agreements that we will not disclose details of what is going on or in most cases the names of the companies.

We have dealt with a large chemical company that wants to look at the effect of microgravity on certain reactions that are inherent in the business of the company.

Not all of them are large companies. We have dealt with a small company that has a process that will be very important to the development of products in the chemical and biological fields, and they want to try their process out in a microgravity environment. In that case, the first flight will be on a NASA aircraft that is operated by the Marshall Space Flight Center.

We are dealing with a biological and pharmaceutical company who would like to take advantage of the electrophoretic separation process that McDonnell-Douglas has proved in early orbital flights in the orbiters, and this would lead to the development of processing in space in a production mode.

A large chemical company that we have opened a dialog with has agreed to consider a long list of projects. I think there are about 12 that they are now looking at, from which they will select some promising projects, and then they will want to prove those projects in an orbiter, with a view toward space station operation later on.

We have had a series of meetings with an industry group that wants to get into the business of monitoring situations on Earth that are inherent to its industry, and that would be a long-term operation that would require on-scene manned interpretation of what is seen.

And we are hoping to develop what may turn out to be a consortium to fit out and operate a commercial space station laboratory for material processing support and other research work that companies who are not able to go into space themselves would like to have conducted for them so that they can further develop their ideas and their research about manufacturing processes in space.

Among the industries we have been talking to, as I have suggested, are chemicals, pharmaceuticals, biological, genetics, electronics, oil companies, metals, and several conglomerates. But as we talk to industry we learn that there are barriers perceived to some of the things they would like to do. Some of these barriers are technical and some of them are related to cost, and a fair number of them relate to the question of working with Government. For many of these people this is an unfamiliar situation, and there are problems about proprietary information and about how to enter into an agreement with the Government.

Because these have become a part of the landscape, we have focused on them quite a bit. And NASA has begun to study very carefully the whole array of barriers, and fortunately they are responding in a very positive way. And I think it is important to recognize that NASA is doing this.

First of all, NASA has established as one of its top objectives in a statement from Mr. Beggs, the NASA Administrator, the objective of expanding industry opportunities in space. And to meet this objective, this means that there will be some reorientation of how NASA does some of its work; and where many people have tended to focus on internal NASA direction of projects, there is beginning to be a new openness to initiatives.

NASA, as I suggested earlier, is specifically studying in a task force mode what these barriers are that we and they have identified, and they are developing feasible remedies to overcome these

barriers, and incentives for firms to get more interested in what can be done in space.

There are some outreach initiatives in several different directions, some tied to increased utilization of the space station or the space transportation system, others related to the whole subject of space commercialization and trying to simplify how firms deal with NASA, a third dealing with material processing in space, and of course earlier I mentioned that our work on the proposed space station is a very important outreach initiative, because it has opened doors and opened the minds of a lot of people who had not seriously thought about a space station before.

And finally, I might mention that NASA is now drafting an operational policy in order to take a more organized approach to dealing with commercial applications in space, both as a NASA initiative and to respond to initiatives from industry of all kinds. And I think this will knock down many of the barriers that we have talked about.

I think that if NASA continues these very thoughtful efforts and if they are supported where necessary, if legislation is needed or if the support of the administration is needed, I think that a partnership will result and this will lead to a rejuvenated technical leadership for the United States, and several of you gentlemen have mentioned how important that leadership is to our national goals and to the exercise of our foreign policy. I think this is something that is a very important underlying reason for taking on such an initiative.

But in particular, a space station will be of great commercial value to the United States as industry learns to make use of space in a productive mode beyond the research mode. The first economically successful applications of space, and especially material processing in space, are probably not far off, and when that happens it will trigger a great many other initiatives, we are confident.

There are many other things that Government can do to help the situation along, and I will just briefly categorize them in terms of establishing and making known clear objectives. Industry needs to know that Government is behind the commercial use of space, and that needs to be demonstrated in some clear and convincing ways.

Outreach. We have talked a little bit about that, explaining to people what can be done and how to get there with the help of the Government, providing the science that answers some of the unanswered questions about space phenomenology, a better communications program, and generally opening up communications with all the sectors of industry that might benefit.

We do not know what all of them are yet. That is the interesting thing about space. We are convinced that there is great potential. We know that each year will mean the discovery of new ways to make use of it, especially when we are able to work on orbit long-term.

Access is important. We have to provide clear entry points, and people oriented to helping when industry approaches.

Assistance will be important. In some cases that could take the form of grants or cooperative efforts to get over that early hump of facing a rather staggering challenge and high costs.

The stability of Government programs and policies is something we hear mentioned very often as an important element: Can industry count on a Government entity downstream if they spend money now to get ready for that? Can they count on consistent support in such areas as tax relief and investment credits?

And finally, the most important step that can be taken to encourage development on the part of industry of its initiatives will be the establishment of a funded civil manned space station program. We know that if we had such a program today a great many more people will be willing to invest the time of their top planners and scientists in getting something ready for when we can make more use of space.

You asked about alternative approaches to working in space, and there are several fairly obvious ones that I think it would be important to address. First of all, the question of an unmanned platform as a way to do the things that we are talking about. Many of the things that have been identified have some potential for operation on an unmanned platform, and there are feasible platforms in development. The Germans have put up their SPAS, which we have seen operating from the space shuttle.

I think it is very important to note that there are very few processes, even on the ground in the United States, that can operate long-term without manned intervention. And we think this is going to be the case for probably the next 15 or 20 years, particularly where the process involves some kind of mechanical action, or where there are frequent adjustments to a process needed, or where there are logistics issues to be addressed.

The people that we have dealt with in almost every instance are not willing to invest in something that they cannot adjust and operate under manned supervision in the near term. It is pretty clear that they are willing to go if there is a friendly manned environment where they can work long-term without interruption. But there is a lot less inclination to go for the unmanned missions at this time.

As processes are refined and as automation is further developed in some of these processes, certainly it is possible that many of them will move to an unmanned situation. But probably even then they are better served if they are unmanned operations flying in company with a nearby manned support operation that can provide the intervention, so that you do not have high investment orbiting around the Earth and producing nothing. So that quick reaction and attention seems to be important.

The second alternative that is suggested is extended operation on orbit of the space transportation system. I think this is a very important step to inquire into, and we know that the orbiter has some potential for extension of its mission time with probably a fairly limited investment. That extended orbital operation could be a very important step to more feasibility demonstrations of material processing in space and the kind of continuing processes that some of these firms are dealing with.

But I do not think it is the ultimate answer. I think we need to view the space transportation system as it exists today as just that, a transportation system which is optimized for that purpose, but not the sort of investment that you would leave in orbit long term.

Probably we can think in terms of 3 or 4 weeks or perhaps several months of missions. But that does tie up a very important national resource and reduces its flexibility and its ability to support the payloads that we now forecast for it. I think it is an important interim step toward a space station and one that does merit the attention of the Congress and of the agency.

Another alternative would be a manned space station pretty much as NASA has conceived it, but bought and paid for and operated entirely by private industry, and that is something that has been given some attention and we have looked at it and we have talked to people about it, and our present opinion is that it is just too much to swallow for a diverse range of industries.

But it is an opportunity for investment in terms of some part of it. The present concepts for the space station are modular. I think it is quite possible that NASA might stimulate interest that would lead to investment in some part of that by private industry.

The most likely part that we see right now in our work would be the commercial orbital laboratory that I spoke of, and there is interest in that, not only on the part of the technical operators but in terms of investment firms that see that as potentially a very promising investment. So we are proceeding to develop that point and it may become an element of the space station.

A last alternative that we might think about very carefully is the fact that another country might undertake to do something like this manned space station we are considering, and steal the march on us. There is a lot of interest being shown by some of our friends overseas, particularly Japan, Canada, France, Germany, Italy, and the European Space Agency.

I think it is clear that Canada wants to support us with particular efforts, as they have already in the orbiter. But many of these countries move fairly quickly in technology areas and have surprised us over the last couple of decades in other areas, and have known how to take technology to market.

It could well be that if they find that we are not going to continue with the initiative that we have been planning and in which these countries have participated already, then somebody else may take that brass ring out of our hands. I think it would be a real mistake if we lost a large measure of our technological leadership by failing to acquire this ultimately very significant national resource. So I think we need to think about that question at the same time.

I also have no doubts that a permanent manned presence in space of this sort will ultimately provide very useful experience and technology to help meet our national security needs. And as you know, we are beginning to talk more about the defense technology measures that might put us in space with defense, and that would be supported by the kind of things we can learn in a manned space station.

What is needed now is a formal program leading to an operational civil manned space station. A program initiative of this sort would give industry the justification to invest more of its resources in developing the projects that will put business in space, and will develop for the United States considerable economic and national resources.

I fully believe that the commercial development of space, and particularly the development of the space station, are in the national interest and that the Government has an urgent and central role in moving forward with these efforts. We are very enthusiastic about what we have seen being studied, and I hope that as you complete your factfinding that you will find a way to support this effort.

I would be pleased to take any questions you might have.

Senator GORTON. Thank you very much, Mr. Wood.

I would like to start out by following up on a couple of these last comments you made about alternatives. You, obviously, do not find any of the alternatives to be as satisfactory from the point of view of the missions which your clients and potential clients intend to follow. But can you quantify that? Of the missions, of the uses of a space station, what proportion would be filled by an unmanned space platform such as Leasecraft and what proportion would not?

Mr. WOOD. Leasecraft I think is a very promising national resource in addition to a space station, and in fact we see it as complementing space station. I suggested that probably a space station would be a modular situation. It would be probably, basically, a cluster of modules. But we also see in the concept the likelihood that there will be unattached modules in company, and Leasecraft could very well be one of these.

So we perceive Leasecraft not as competition for space station, but as a complement to it. I think probably some of the early test operations are well supported in Leasecraft and then when operations become highly refined in such areas as separations of material they have the promise of long-term operation in Leasecraft.

I am not able to quantify what that means in terms of percentage of the number of things going on, because the nature of our work has been such that we have dealt in a one on one situation with firms that have expressed an interest in at least talking, and on limited resources, and so far we have probably talked to something like 60 firms and we are dealing in a fairly concentrated way with about 35.

Other investigators have looked at a similar number. Coopers & Lybrand, for example, has a parallel contract to ours. Out of these we get fairly advanced prospects in numbers that run to dozens rather than hundreds. So the statistical meaning is not there.

But there is enough of a sampling to tell us there is a potential. So I am estimating that in the period between now and the year 2000 probably something like two-thirds to three-fourths of the different kinds of initiatives will have to get their start on a manned space station, and that that same manned space station in its laboratory functions will plant the seeds for another generation of applications, a second wave, so to speak, of industrial applications, that again will have to have the early years under close supervision. Some of them will probably go on indefinitely in the manned supervision mode.

So I think we are saying that that alternative is more of a complement than a competitor for the next couple of decades.

Senator GORTON. What about an extended duration orbiter, just taking the present shuttle and modifying it so that it can go two or three times as long?

Mr. Wood. I am going to have to yield to NASA on the economics of that, and I believe some comparisons have been done. But I think logic tells you that you can sometimes use a pair of plyers as a wrench, but if you are going to do a lot of wrench work you are better off with a wrench designed as a wrench.

The orbiter was designed as a transportation system. It has a capacity to do short-term research. But in terms of its economics, it is a resource that ought to turn around. You can use a ship to store grain in, but it is a very poor economic use of that ship and you worry about the cost of a lay day. You can use an aircraft to hold a party in, but the primary use of an aircraft is to get from here to there.

The orbiter really was designed as a transportation ship, transportation craft, to take people and things from the surface of the Earth to low orbit. Something else can be designed that does not have to undergo the rigors of launch and reentry and, therefore, can be optimized for long-term manned presence in space.

So I think logic tells you that the economics would suggest that you not use orbiter as a permanent solution for long-term processes.

Senator GORTON. Thank you.

NASA presently has three working joint endeavor agreements with commercial firms—McDonnell-Douglas, Fairchild, Micro-Gravity Research Associates—for the promotion of commercial space ventures. Of the firms with which Booz-Allen is negotiating to develop commercial opportunities on the space station, how many joint endeavor agreements or similar arrangements do you think are likely to result?

Mr. Wood. Currently we have four agreements in process. We have at least four that I think have something like an 80 percent probability of leading to agreements. In those cases, agreements are in draft.

In some cases they are joint endeavor agreements that would lead to shuttle flights; in other cases they are called technical endeavor agreements, which involve similar cooperation but not shuttle flights at that point.

I would project that, from the experience we have so far, probably we will be reaching something like 10 agreements within the next year, and all of these would have the promise of ultimate commercial production work in orbit.

Senator GORTON. Thank you.

Senator Heflin.

Senator HEFLIN. Mr. Wood, your testimony is quite interesting. Basically, the user development of space station is something I think we in Congress are very sensitive about because it involves cost-benefit and certainly we are in the syndrome of cost-benefit ratios whenever we spend any type of money.

It might be helpful if you could be more specific in an appendix to your testimony as to these 35 different companies. I notice there are some that are publicly known: Johnson & Johnson. But you might elaborate and give us your evaluations of those potential uses of a space station in a microgravity environment, and then you could possibly categorize those with more specificity. I know you cannot reveal their names, but could you give us some more

details. I think that might be helpful to us in the overall evaluation.

I suppose from your studies you see an interest from other countries. From your studies thus far, is it your opinion that it would—from the viewpoint of the investment by the Government, that it will bring benefits which would exceed the cost of the development of a space station?

Mr. WOOD. What we have seen in terms of quantification is a series of particular products or processes where the market is viewed as something like \$100 million for each one of them in many cases. We have come to think of that as perhaps a threshold for the most promising endeavors, and that in these instances it certainly would be cost effective for industry to make the investment which will involve developing the process, preparing equipment, training operators, and then paying for the cost of the orbital flight and some rent on a manned space station.

These companies have run the numbers and have found it worth considering very seriously, to the point where they are investing the time of their top research people in continuing to develop the process. So the economics are a very important part of the early consideration by these firms and they are finding the numbers are promising, as near as you can project what costs might be at this point.

We are talking about an initial space station capability that would be substantially below \$10 billion in all probability, and from that you can begin to figure out what the cost would be.

We will be happy to supply the kind of detail you mentioned on the specific contacts we have made, perhaps generalizing where our requirements dictate.

I should point out that your mention of Johnson & Johnson refers to a very successful venture that we cannot take credit for. I think much of the credit goes to people in your State, Senator, because the Marshall Space Flight Center did some of the early work in electrophoresis that probably formed the principal basis for the work of McDonnell-Douglas and Johnson & Johnson in their very promising partnership.

There are some very forward-looking people in NASA who have provided much of the science that we are now able to use in our seed concepts as we talk to these firms, and that is a good example. We believe that that is going to be a very successful process and that it is not far from demonstrating its first products.

Senator HEFLIN. Well, if there is a market for a microgravity environment for industry, the alternatives for producing that environment are basically a manned space station or an extended orbiter. Do you have any opinion as to whether or not in approaching this, it should be done in a progressive manner, whether there are certain approaches that should be followed?

Do you have any feelings relative to those?

Mr. WOOD. Yes. We believe that moderation is important and that the technology needs to be in hand, and most of it is in hand, some more is in planning for development in the next few years; and that technologically it is quite possible to achieve the initial capability that I understand NASA has in mind for, say, a 1991 or 1992 operational capability.

But that space station will be evolutionary, and that the capability perhaps 10 or 15 years later will have grown using that initial capability as a nucleus. It is a very adaptable kind of situation that is planned, and you can attach new modules and add new capability.

This is an approach which hedges your bets, so to speak. It is an approach which can be achieved without a major perturbation to the total level of funding of NASA as we understand it to be planned, so that annual increments of investment could be handled without damage to the science budget, largely supplanting the investment that has gone into the development of the orbiter itself and to the systems that support it.

And I think this evolutionary approach will maintain for us the technological leadership that we think is important, and yet not risk large amounts of money in something that is not built on solid technology that we have confidence in today.

Senator HEFLIN. I notice in your testimony you said that the private sector was very interested in the space station and the commercial opportunities in space. Sometimes we use words generally. I make some sort of distinction between the words "interested," "involved," and "committed": If you are interested, you are willing to spend someone else's money; if you are involved, you are willing to spend your brother-in-law's money; and if you are committed you are willing to spend your own money.

Now, how would you classify the private sector's approach toward the space station at this stage?

Mr. WOOD. Well, let me start first of all with something that we discovered and we did not go looking for, and that is that as we have become a little more visible because we are talking to a lot of firms and because of appearances like this, a surprising number of investment firms and venture capital firms have made contact with us.

We now have a list of 17 such firms with very recognizable names that have indicated their readiness, perhaps eagerness, to invest in space. And these are firms that are famous for casting a very cold eye on opportunities and looking at them from all sides, because they then have to undertake public offerings and they have to go through the due diligence.

And if these people, who are traditionally pretty conservative about where large amounts of money go, have expressed this kind of interest and have, in fact, begun to back some space ventures, are willing to put money in this direction, I think it is a very good sign, because they do examine things very carefully from the standpoint of technology, from the standpoint of risk, and from the standpoint of return on investment.

Recognizing that return on investment in space is a long-term prospect—typically, you might have to wait 8 or 10 years to get your money back—then I think it is significant that we have this kind of interest. People are coming to us. People are backing ventures.

For example, Orbital Sciences Corp. is about to undertake a venture to build an upper stage that will take payloads from low Earth orbit, where the shuttle and the space station would be, to the geosynchronous orbit. They have obtained solid backing from

several large venture capital firms, and that is in progress right now.

You saw that there was an offer to privately build a fifth orbiter, and the money behind that was conservative money, and yet it said that was a good place to put its money.

The second point is about commitment of money as you define "commitment," and here I would like to mention that people have alternative ways to invest the time of their best brains, their thought leaders, and their conceptual thinkers. And what we are saying is that a substantial number of, say, 70 firms that are being contacted between Booz, Allen and Coopers & Lybrand are investing the time and money of those key people.

Now, that is not big dollars. We are talking about under a million dollars a year for most of those companies going into this kind of thought. But it is money that they could spend on other opportunities, if they did not find this promising.

So I think it is significant for this stage of things, and when there is a program, then I think we are going to see a substantial increase in that activity.

Senator HEFLIN. Do you believe that NASA has done an effective job in bringing the private sector into the planning of the space station thus far?

Mr. Wood. I think perhaps if NASA had been able to commit more resources to the effort, and as they are able to commit more resources, they will do a larger job of it. But I think NASA has very properly balanced its attention in the direction of the aerospace industry on the one hand and the nonaerospace user industry on the other, and they have directed it to a number of different industries, six or eight.

So I think, considering the fact that discretionary money for NASA at this point in the program is quite limited, it is the beginnings of an effective job. More needs to be done, and if this takes the status of a funded program, a great deal of investigation will have to be directed toward this partnership with industry, and particularly with nonaerospace industry that is new to the scene.

Senator HEFLIN. Thank you.

Senator GORTON. Senator Tribble.

Senator TRIBBLE. Thank you, Mr. Chairman.

Mr. Wood, one of the key concerns on the part of the business community seems to be that there is a lack of commitment by the Federal Government to a long-term strategy and investment in space. They do not want the Government suddenly to lose their interest and go on about other things.

In a recent article in Aviation Week this last month, several corporate officials who have met with every American President since Dwight Eisenhower said that Ronald Reagan is more openly enthusiastic about space than any other American President. That raises two questions in my mind.

First, how do we capitalize on this enthusiasm for space on the part of a clearly pro free enterprise President to get business involved in space? And two, is a space station program enough, or should the President propose a broader space strategy?

Quite frankly, my interests are much more strategic than they are tactical, and it is to that end that those two questions are posed.

Mr. WOOD. I believe you are going to hear from Vic Reis later this morning, who has been a lot closer to the President than I have, and I am sure that he can expand on anything I can say.

We are very pleased that the President reacted with such favorable enthusiasm when he was told about the concept of the space station. My understanding is that he did that on the occasion of a luncheon meeting with some of the captains of industry who had directed their thoughts through these routes that we have discussed today.

I think that enthusiasm that he heard about from them was partly supported by the fact that NASA was actively studying the question of the space station and that, further, NASA has formed a commercialization task force, which demonstrates a positive attitude toward working with industry. And these two signals from NASA within the last year tell industry something that is very helpful for now.

It loses its meaning totally if you cannot stay on this roll. People are interested, but we have to keep them interested, and we have to maintain the communications and maintain this dialog that is begun and then make it meaningful.

We have been saying there probably will be a space station program, and they have been saying, we probably will be interested. And some of them are saying, we have enough faith in that to start putting some serious investment in people and hardware. But to keep that going and to keep that kind of faith, there had better be a program before long or they will turn to something that they can put their anchor in, something a little more solid.

So I would think that giving this program status would be the first way to keep whatever momentum we have now and to keep that enthusiasm up.

I think the second point would be a stronger statement from the administration than we have had on its specific program for space. Like you, I like to think strategically, and I would like to see a manned space station as an element of a grand strategy.

I do not think we need to fully form that grand strategy before we take this elemental step, because I have great confidence that this is a correct step and probably one of the most promising in the near term. But I think we have to look beyond that.

We have talked in scientific terms about resources that might be taken from space. The asteroid belt may have resources that are important to us. The Moon may provide important materials. There probably are some very solid returns to be obtained from going beyond low Earth orbit or even beyond geosynchronous orbit, and we need to have a program for the next 50 years, certainly.

I think it is very timely for such a program to be endorsed at the national level. NASA has done a lot of thinking in this direction. The National Academy of Sciences has done some thinking. And I would think it would be entirely appropriate for the administration to form such an effort now and to specifically define a broader strategy.

But the first step is to enable industry in the near term, in the next 10 years, to begin to operate and take advantage of what we know.

I also think it is a very important thing that we provide enough resources to keep the scientific work going. The space sciences work is very important toward expanding the range of things that can be done in space, and there are a great many unanswered questions. There also has to be investment in science where you do not know what the return might be, because this provides a range of answers from which new ideas can generate.

So balance, as you gentlemen have recognized already, is important to the space program as a whole and certainly important to what goes with a space station effort.

Senator TRIBLE. Thank you, Mr. Wood.

Senator GORTON. Thank you very much, Mr. Wood and Mr. Stark. We appreciate your contribution.

[The statement follows:]

STATEMENT OF PETER WRIGHT WOOD, SENIOR VICE PRESIDENT, BOOZ, ALLEN & HAMILTON INC.

Mr. Chairman, members of the Subcommittee on Science, Technology and Space, I am Peter Wood, Senior Vice President of Booz, Allen & Hamilton. It is an honor to appear before this distinguished committee as you examine the concept and planning for a United States Manned Civil Space Station—a place for our people to do significant long term work on orbit.

Booz, Allen is a leading professional services firm consulting in management and technology to Government and industry worldwide. Our work includes nearly twenty years of consulting in space systems management and technology, for NASA and the aerospace industry. I have been with Booz, Allen for sixteen years, principally in defense and space activities.

In 1982, NASA renewed its earlier studies of a manned Space Station. Plans for such a project had figures prominently at the start of the shuttle program. Within the last year, concurrent Space Station Needs, Attributes and Architectural Options (SSNAO) studies were carried out under contract to NASA by eight aerospace firms. Each study was to include the identification of missions, and especially commercial users and their "missions" or applications. Booz, Allen was a subcontractor to McDonnell Douglas Astronautics, with the primary function of undertaking commercial user development in non-aerospace industries, an activity we are continuing now under direct contract to NASA.

Our approach has been to meet with receptive firms in various industries, to introduce the attributes of space, and to start dialogs on the basis of our seed applications concepts for making use of such attributes as microgravity. These discussions have the objective of stimulating forward-looking industry managers, planners, and research leaders to conceptualize activities which can lead to profitable ventures in space. We would then provide assistance and access to space technology, with a view toward early proof of concept, typically in NASA low-gravity facilities, including shuttle flights. This program has begun to stimulate innovative thinking in firms in a number of fields—crystal growth for communications and infrared sensing equipment, biological separations for the production of valuable pharmaceuticals, containerless processing to produce stronger alloys, and purer production of optical glass for instruments and communications—to name a few. The focus is on processes that gain a special advantage from the space environment, and on products with high market value. While our deliberations with such firms are often proprietary at this stage, in the aggregate we can report a growing body of positive response, and increasing interest over a fairly broad range of subjects. We have gained considerable confidence that a manned Space Station will attract commercial interest, and will provide a place to carry to material processing in space.

Among the industries where promising applications are being planned are chemicals, pharmaceutical, biological, genetics, electronics, oil, metals, and several conglomerates.

Progress in industry faces numerous barriers. Part of our work, and that of others, has addressed identifying obstacles to the commercial use of space and how

to overcome them. While some obstacles are technical or cost related, many are found at the interfaces between industry and government.

Fortunately, NASA management has responded to the identification of such obstacles in some very constructive ways this year: (1) by setting a major agency objective to expand opportunities for industry; (2) by intensive study of barriers to commercialization and the identification of appropriate remedies and incentives; and (3) through several commercial-user-oriented outreach initiatives—tailored toward shuttle utilization, space commercialization, materials processing in space and commercial applications of a manned Space Station. Finally, (4) a new operational policy to foster commercial applications of space is being crafted. If these thoughtful efforts become a way of life for NASA, and if industry interest continues to grow, the partnership will result in rejuvenated technical leadership for the United States, and in particular, substantial commercial value in a manned Space Station. And the first economically successful applications will trigger numerous others.

We have been impressed with the growing amount of private sector interest in space initiatives during the year and a half of Space Station planning. In particular, the number of financial and venture capital firms openly ready to invest in space seems to have grown significantly. This trend further brightens the outlook for commercial interest in space station use.

Such a space station as NASA now contemplates will, on a long term basis, accommodate many of the commercial process and product applications now being studied by industry. But it fosters further activity by enabling the development of space technology and operational techniques—in fields such as space construction, earth and space observation and monitoring, satellite servicing, transportation node operation, and human endurance studies. Experience gained from a permanent presence in space will also yield special benefits to national security applications of space.

A manned Space Station will also prove useful by providing an on-orbit laboratory for the investigation of space phenomena and science. Extended manned operation will enable experimenters to assess the results of experiments in progress and make appropriate changes as their work continues. Such a facility will be of value to government, industry, and academia, and provides one means for opening the door to an even broader range of economically meaningful commercial users of space, as well as solutions to needs in such areas as health, electronics, and critical resources. In fact, our contacts with industry during our user development work have indicated that there is a market for a commercially-operated fee for service laboratory which might well represent an attractive investment and would very likely lead to a second generation of space-based industrial processes.

We have reviewed the eight Space Station studies completed early this year by aerospace contractors, and conclude that anticipated technology will support the initial Space Station capability NASA proposes. Not restricted to a single spacecraft, the Space Station can include space platforms or free flyers in company with the central complex. This enables isolation of hazardous operations, processes sensitive to disturbances, or applications requiring precise spacecraft orientation, while still keeping the benefits of long-term continuous operation supported by the ready availability of manned intervention and logistics resupply. According to cost projections and budgeting studies we have reviewed, a substantial initial capability appears to be deliverable by the early 1990's within a space budget not significantly greater than the current levels. In our view, while private initiative is unlikely to result in an equivalent national capability, nevertheless private sector investment may provide some component of the planned Space Station under appropriate agreement. For example, a lab module might well be fitted out and operated, for use by government and private sector customers, by commercial interests, thus relieving some impact of a Space Station on the Federal budget and further building the partnership between government and industry.

International interest in the U.S. Space Station concept has been significant, with study participation by Japan, Canada, France, Germany, Italy, and the European Space Agency. Such interest suggests that if the United States does not take the initiative, we may fail to acquire an ultimately significant national resources, and will lose a large measure of the technological leadership that has served our national interests so well. Our economic strength in the future will increasingly depend on the vigor with which we exploit the potential of our own technology base.

On a broader scale than Space Station, the commercialization of space in all its forms will have increasing implications for our economy, security, and world leadership and prestige. We have observed the value to Japan's economy gained through partnership of government and industry. Space offers one of several opportunities for our government to demonstrate leadership and support to industry. There is a

challenge to both sectors to use vision, creativity, and perseverance to make such a partnership work for us—and not to overseas neighbors. Space Station, which would be well supported by the Space Transportation System, appears to be a very promising element of the commercial development of space. I have no doubt that a permanent manned presence in space will also ultimately provide useful experience and technology to help meet our national security needs.

What is needed now is a formal program leading to an operational civil manned Space Station. A program initiative will provide industry with the justification to direct significant resources toward the private sector projects to develop Space Station's economic and national potential.

I fully believe that commercial development of space, and particularly development of the Space Station are in the national interest, and that the government has an urgent and central role in moving forward in these efforts.

REPRESENTATIVE SPACE STATION USERS CURRENTLY IN DEVELOPMENT BY BOOZ, ALLEN

Large chemical company—investigation of effect of microgravity on chemical reaction.

Small private company—investigation of effect of microgravity on proposed industrial process.

Biological pharmaceutical company—possible application of electrophoretic separation to a specific material.

Large chemical company—actively reviewing a series of candidate projects.

Industry group—considering an earth monitoring process.

Planned consortium—possible commercial space station material processing laboratory.

NASA IS WORKING ON WAYS TO REMOVE OBSTACLES TO SPACE COMMERCIALIZATION

Setting objective to expand industry opportunities in space.

Studying the barriers and developing remedies and incentives.

Outreach initiatives, ties to shuttle utilization, space commercialization, material processing in space.

Drafting of an operational policy to foster commercial applications in space.

GOVERNMENT CAN HELP

Objectives—clear, supportable, realistic, authoritative.

Outreach—demonstration of cooperation, research to provide answers, a better communications program.

Access—clear entry points, trained contact staff, streamlined procedures, simplified interface, clear criteria.

Assistance—available at every stage, oriented to need, adequately supported.

Stability of programs, policies, and budgets related to commercialization.

INDUSTRY CONCERNS FORM OBSTACLES TO SPACE COMMERCIALIZATION

Space commercialization supports national goals.

Obstacles include technical barriers, economic barriers, government-related concerns.

TECHNICAL BARRIERS

Problems in conceptualization applications.

Gaps in science and phenomenology base.

Technical risk identification and management.

Technological competition and obsolescence.

Human capabilities versus automation.

Intellectual property rights.

ECONOMIC BARRIERS

Cost of entry and operations; timing of entry; cost risk and image issues; long pay-back time; uncertain return; and alternative investments.

GOVERNMENT RELATED CONCERNS

Unfamiliarity with working with Government; finding the entry point; multiple viewpoints; finding the decision makers; running the gauntlet/watching the shuffle;

program uncertainty; instability of programs, policies, and budgets; the electrorate; military; international; competing programs; and tax relief—space tax credits.

QUESTION OF SENATOR GORTON AND THE ANSWER THERETO

Question. How important is it to the private sector firms with which you have been in contact that they have a permanent manned presence in space for present or future use, compared to an intermittent presence as offered by Leasecraft or an extended duration orbiter?

Answer. Most of the private sector firms with which we are dealing are more concerned with the short term issues of how to identify and develop the activities they would like to pursue in space than with the ultimate implementation of them; thus we have not had extended discussions with many of them on this particular issue. However, from our understanding the general nature of the activities which are of interest, and the implications which such activities have for whoever is conducting them, certain conclusions can be reached.

First and foremost is the question of access—will users actually be able to tend routinely the operations they are considering, or will it only be possible with great difficulty? If the space shuttle appears to have the long term backing of NASA, the Congress, and the Administration, then basic transportation would be less of a concern. However, if it appears to industry users that heavy or dominant government (NASA or DOD) use of the STS begins to give the appearance of inhibiting routine access from the ground, only a permanent manned presence in space would offer a comforting alternative.

A second area of concern would have to do with the two activities common to all space activities—R&D and production—and the means by which they can be carried out in space. In the R&D phase, the firm will want to conduct experiments, make any necessary adjustments to its equipment or procedures, and continue their work. Such activity is poorly suited to a Leasecraft (which is an unmanned platform) for two reasons—the need to automate the entire experiment (which raises the cost, often substantially and substantially reduces operational flexibility and reliability for operations involving mechanical, fluid, or gaseous activity)—and the relatively long time between STS visits (which precludes prompt analysis of results and resumption of the development). An extended duration orbiter (EDO), while limiting compared to a permanent space station would be more suitable than an unmanned platform for R&D, since the work can be man-tended and adjustments can be made within the duration of the flight. A manned space station is better suited to R&D than either a Leasecraft or an EDO, since it offers the man-tending of an EDO plus an essentially unlimited period within which to make adjustments and continue experimental work. In addition, a spare station would permit repeat experiments with the same or slightly modified equipment or process parameters, without incurring additional launch costs for the hardware and any company attendants. In the ideal case, a commercial laboratory on a space station is probably the most cost effective approach to conducting space R&D, since most of the equipment (and the module in which it would be installed) would have to be launched but once, with periodic STS visits to pickup and deliver materials and personnel. Companies would only have to pay for their share of the equipment, materials, personnel, and transportation costs. Recognizing this, we are presently working with a group of six investment banks and venture capital firms and a commercial laboratory who are interested in funding and operating the laboratory modules on NASA's initial space station. Until a space station is available, the STS will be used to provide the research necessary to develop the first space-based production operations.

In the production phase, for certain activities which lend themselves to sufficiently reliable automation and left to operate for months at a time without tending, a Leasecraft may be more attractive than it is for R&D. The use of an EDO for production is only reasonable if relatively short runs (on the order to a month) are sufficient, and man-tending is required. It also presumes that the operation can afford, in effect, to lease the STS as a surrogate space station for such periods. Use of a transportation facility is rarely an economical approach to an extended term production requirement.

In summary, the early decades of industrial development in space will, in my judgment, be best served and fostered, in terms of both technology and economics, by access to a permanent manned space facility in earth orbit, supported by a reliable, cost effective transportation system.

In response to a request from the Subcommittee for further details about Booz, Allen's contacts in the private sector, on behalf of NASA the following briefly char-

acterizes our current chief private sector candidates. Confidentiality agreements restrict our ability to fully describe these interactions:

A bio-pharmaceutical firm is interested in separations applied to pharmaceutical production.

An industry association is interested in the use of remote sensing to address industry needs on the ground.

A small private company is interested in testing a new separation process.

A large chemical company is interested in investigating the effect of microgravity on one class of chemical reactions.

A group including technical and financial concerns is interested in operating a fee-for-service laboratory as a component of the proposed space station.

A pharmaceutical firm is interested in chemical experimentation in microgravity.

A chemical/pharmaceutical company is considering fermentation experiments in microgravity.

A major laboratory is considering some microgravity experimentation.

Senator GORTON. Our next witness will be Dr. Victor Reis, former Director of OSTP. If Dr. Reis will come forward, he may start.

STATEMENT OF DR. VICTOR H. REIS, FORMER ASSISTANT DIRECTOR OF THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT

Dr. REIS. Mr. Chairman, the decision on the space station will set the direction of our civil space program and our civilian space agency, NASA, for years to come. Because of its importance, this decision should not be made without thorough investigation and debate. Thus, I applaud this hearing and greatly appreciate the opportunity to express my views.

The questions you asked in your invitation are simple and straightforward: What are the uses of a space station, are there other ways to do the job, and what are the budgetary impacts? Beneath these questions, however, lies the more fundamental issues of what the U.S. civil space program is all about and what we expect from our space agency. I will answer the easy ones first.

NASA's current long-term concept for the space station includes a permanently manned space station, a man-tended platform and associated free flying, but visitable, satellites. Appropriate constellations of platforms would be placed in 28 degree and polar orbits. The permanent manned space station would be but the first major structure in this far-reaching space architecture.

But in considering capabilities, I believe you should consider the long-range plan and not just the first step. If we assume the long-range plan is successful, all the near Earth missions—science, applications, technology, servicing, et cetera—can be done—and done well—under the space station umbrella.

On the other hand, with one exception, each and every one of the missions can also be done—and done well—by a judicious combination of shuttle orbiters and satellites, if we extend the mission duration of the orbiters. The exception is understanding the effects of extended time in space on human beings.

Further, it is my judgment that a program of orbiters and satellites would cost less, perhaps considerably less, than the equivalent space station program. I believe this is so because of two reasons. First, the requirements for the wide variety of space missions are often so different that the potential savings from sharing platforms will often be more than wiped out by the additional cost of making

them work on the same platform. And second, sharing space with human beings is always costly.

Thus, whatever the budget for the space station, your third question, there is likely to be a lower budget that could get much the same space job done.

What it boils down to is this: If you can do basically the same space station job with satellites and shuttle orbiters at a lower cost, are there any arguments for going ahead with the space station?

There is one. And if it is neither technical nor economic, it is a powerful argument nonetheless. It gets back to the fundamental question of what we as a nation want from our civil space program and from NASA.

Today's NASA was in large part put together to do the macroengineering project Apollo, the manned mission to the Moon. Apollo was not a scientific experiment and it was not undertaken for economic return. It was a statement of national will in an era of intense international political competition. And it was successful, historically successful.

NASA remains much the same organization today as in the days of Apollo. It is organized and staffed to carry out large, complex manned space macroengineering projects. The space station is just such a project and there is no other that fits the NASA mold quite so well. In short, the space station project will provide NASA the central focus and scale that it is organized to do.

The space station is not Apollo and cannot in and of itself yield the same historic impact and degree of political and psychic return. But it certainly will provide some, perhaps a lot, of these real but intangible benefits, and it will retain for NASA a continued large measure of national and international political importance.

On the other hand, rejection of the space station at this time will by no means be the end of NASA or our civilian space program, but it would certainly lead to a different NASA, one much removed from the legacy of Apollo and one most likely with a lower political content.

To my way of thinking, Mr. Chairman, this is the fundamental issue of the space station decision: Is the additional cost of the space station worth maintaining NASA as a politically potent organization, one which might provide the Nation with the potential for significant political and social benefit?

That is not an easy question to answer, and it has far more to do with judgment, political judgment, than it does with technology or economics. NASA is an organization with a critical operational responsibility for our total national space program. The national space policy gave NASA more, not less, responsibility. This responsibility is a heavy one, in science, in applications, in commercialization, and particularly in the maintenance of our national launch capability.

Given these responsibilities, it is my personal judgment that the space station development and its concomitant high-profile NASA is the right thing to do, if, and only if, it is not done at the expense of other NASA missions and responsibilities.

If you give NASA the go-ahead to the space station, then you must be prepared at the same time to provide NASA with the additional resources—funds and talent—to move down this path. If you

do not provide the wherewithal, then you run a serious risk of causing irreparable harm to the national space program and to NASA.

The space program and NASA are in fact at a crossroads, and what we decide to do about the space station and how we decide to do it will firmly and inevitably set the direction for the Nation's future in space.

Thank you.

Senator GORTON. Thank you, Dr. Reis.

Your testimony suggests that all but one of the high-priority near-Earth missions can be done well by a judicious combination of shuttle orbiters and satellites. Let us assume that we chose to use that judicious combination of shuttle orbiters and satellites. What effect in your view would that decision have on a later question of whether or not we should develop the space station? Would it be preemptive?

Dr. REIS. If you chose to move in the direction of satellites and extended orbiters, I believe you will eventually end up with a space station. NASA first started looking at this a number of years ago, and in fact Marshall Space Flight Center developed the concept where a space station would grow in an evolutionary manner from the orbiter itself.

So if you moved in that direction, it would not preclude a space station at all. You could in fact use the orbiter, if you will, as the first stage of the space station program.

Senator GORTON. So we are not in a preemptive either-or situation?

Dr. REIS. I do not think so.

Senator GORTON. As you well know, in April the President requested the Senior Interagency Group on Space to consider four potential scenarios for the continuation of our manned space program. We do not have any announcement, either from the group or from the President about the results of this study.

But last month the White House announced that it is coming up with a strategy that will enable this country to take the high road in space. Is it your view that the administration is going through the same process of evaluation you just followed, that it is weighing this intangible national prestige against cost and perhaps an inability to justify those costs from a purely technological basis?

Why have we not gotten that answer, in other words, yet?

Dr. REIS. I do not believe you want me to describe the excruciating manner in which interagency processes work, Senator, except to remark that they often work extremely slow. And the Senior Interagency Group for Space is really no different than most of the others.

Each of the agencies wish to make sure that their particular interests are cared for. And there is always a great deal of word-smithing, backdoor maneuvering, and all that sort of bureaucratic horse trading.

There may also be the problem that when you get to the highest levels of the interagency process, the issues can become bogged down in technicalities so that the principals become reluctant to make decisions. That tends to slow down the process. I am sure that never happens in the Senate.

Senator GORTON. Never.

What impact should result from increased interest on the part of foreign nations, especially friendly foreign nations, on this decision, and what impact is our decision likely to have on them? That is to say, if we take the more conservative view is it likely that a number of these nations will be unhappy with that decision and will go out on their own?

On the other hand, is there some real likelihood that they would join, from the point of view of fiscal contributions, to a space station strategy?

Dr. REIS. I do not think there is any nation, with the exception of the Soviet Union which is capable of starting a space station project of any size. I think some nations will—on the other hand, be interested in cooperating with us if we moved ahead with a space station program.

When I was in the Office of Science and Technology Policy, a number of representatives from foreign governments expressed their interest in participating in a space station. But if we do not move ahead with a specific space station, or move ahead in a more evolutionary approach, I am sure they would be more than willing to cooperate in that type of program as well.

In other words, the foreign participation should not be a major swinger in how you make your decision.

Senator GORTON. Senator Heflin.

Senator HEFLIN. You talked about the extended duration shuttle orbiter and free-flying satellites as one alternative to the NASA space station, and you concluded that, with the exception of life science experiments, that is how human beings can live in space over a long period of time, that this alternative could do the same mission as NASA's concept of a space station.

Would NASA agree with you on that conclusion?

Dr. REIS. Probably not.

I think they would disagree about the question of efficiency. I think you can do the same missions with extended orbiters. You just will not be able to do some of them quite as well.

The point I was trying to make, however, is that in making the space station decision that you should not become transfixed by the details of cost-benefit analyses. For example if you look at cost-benefit analyses for the shuttle, they were not accurate at the time they were done and have proven to be a very, very poor method of deciding how you should move ahead in your space program.

I think that so much of the space program has to do with the intangibles of prestige and politics that to go back and to try to compare an extended orbiter with a space station for a specific sequence of missions can be misleading. It is not a bad thing to do, but it may lead you down the wrong path in terms of our whole space program.

Senator HEFLIN. Can the manned space station provide a medium of research that is developmental that cannot be simulated on Earth, in your judgment?

Dr. REIS. I think the space station will provide types of experiments that would be very difficult to simulate on Earth. For example, if you are interested in doing microgravity work over long peri-

ods of time, I do not think there is any other way to do it but a space station.

I think the question you want to ask is, is it important to have man there all the time? I think it is important on many experiments to have man there some of the time. The question is, What do you get by having a man there all the time?

In some cases, particularly if you are dealing in a microgravity environment, man may add unwanted accelerations, so you would rather not have man present all the time.

Senator HEFLIN. You state in your testimony: "Rejection of the space station at this time will by no means be the end of NASA or our civilian space program, but it would certainly lead to a different NASA, one much removed from the legacy of Apollo."

Would you spend a few moments elaborating on that concept? What would this alternative NASA look like?

Dr. REIS. I would suggest to you, Senator, that NASA would look a little bit more like its predecessor organization, the NACA, the National Advisory Committee for Aeronautics, which was an outstanding research organization.

But it clearly did not have a high political profile. It did not have a large public relations staff, Senators and Congressmen did not visit the laboratories, and the citizens at large were probably unaware of its existence. It was far more of a purely technical research organization. I do not think NASA could ever get completely back to that style of operation, even if it wanted to.

In terms of the legacy of Apollo, there has been a lot on the television recently about President Kennedy. Let me read for you just briefly an excerpt from his speech on Apollo. He said:

If we are to win the battle that is going on in the world between freedom and tyranny, if we are to win the battle of men's minds, the dramatic achievements in space which occurred in recent weeks should have made clear to us all, as with Sputnik in 1957, the impact of this adventure on the minds of men everywhere who are attempting to make the determination of which road they should take. We go into space because, whatever mankind must undertake, free men must fully share.

Now, that is pretty heady stuff. That is not cost-benefit analyses. And that is the basis upon which the current NASA was formed. And that is fundamentally the basis upon which, I contend, that NASA is coming to you and asking you for support for the space station program.

Senator HEFLIN. Thank you.

Senator GORTON. Senator Tribble?

Senator TRIBLE. Dr. Reis, I think you correctly identified the central question, but you have failed to answer that question in your own personal terms, but yielded to our political judgment. I would like to give you an opportunity to tackle that question. Is a space station program justified? Indeed, does it need to be justified on commercial or scientific grounds, or is it, after all, something that great nations do, explore and conquer new frontiers?

Dr. REIS. I think it is clear from my statement that I believe it can only be justified on the national perspective. I do not think you can justify a space station, per se, on scientific or technical grounds. I think it will have scientific fallout. I think it will have technical and engineering fallout. I think that perhaps, perhaps, if

we do it right, it will even have economic fallout, but I do not believe it can be justified on those grounds.

I think it has to be justified on broader national grounds, and I believe if you think of it not just as the thing, the space station, but look upon it as a step in a much broader program, then I believe you can justify it, Senator.

Senator TRIBLE. To that end, you have raised my second question. Should we view this program as a goal in and of itself, or should we more properly view a space station as a means to a greater goal? And if so, what should that greater goal be?

Dr. REIS. I do not believe you should think of the space station as a goal in and of itself. I think it is useful as a technical system development goal, because NASA is a system development organization. They have to have a system to develop. You know, you have a lot of NASA engineers. You just cannot ask them to philosophize. They have to build something. And the space station is an appropriate thing for them to build.

In terms of the larger goals, its much more difficult. NASA started off with a very simple, very simple goal, because you were able to pick one thing, going to the Moon, and in that encompass this larger goal of national prestige and political return.

I think you can maintain that type of a goal in terms of exploration, in terms of moving out on the frontiers, in terms of, really, adventure and excitement, without, at this stage of the game, I am going to go to Mars or I am going to go to the Moon, to set up a colony or something like that. I think those are not at all unreasonable things to think about the future.

But I think keeping the momentum going at this stage with something like an evolutionary space station is what needs to be done to maintain that political impact, that psychic return from the space program. There are still a lot of people showing up at every shuttle launch at Cape Kennedy, and there are a lot of people when it lands at Edwards Air Force Base. There is an enormous impact from space that people still are very, very excited about, and it is that excitement, that adventure, that I think great nations can and should maintain.

Senator TRIBLE. Thank you, sir.

No further questions, Mr. Chairman.

Senator HELFLIN. Let me ask one more question. I assume that you would agree that the benefits that mankind have received from the space program if measured in dollars, that the expenditures made by the Government in the space program today have been cost effective. The figure we usually see is that there are many multiple benefits compared to the actual cost. Mankind has benefited thus far; would you agree with that?

Dr. REIS. If you mean cost-effective in the sense that, the way an accountant would define it, I am not sure how to calculate that. If you say, instead, do I think that the money the Government has spent in space has been worth it, I think unquestionably it has been worth it. I think the benefit that the Nation got out of man going to the Moon was in terms of the way we felt about ourselves and the way we felt about the world and mankind in general. I really feel you have to think about space in those terms, and not in the way an accountant would.

Senator HEFLIN. Let us assume that the space program thus far has reaped benefits economically to America. Then I want to ask you this. If that is true, did we anticipate when we started the program that we would have those benefits?

Dr. REIS. I do not think we did. I think part of the reason we received those benefits, Senator, was because we went at it in the sense of attacking the frontier, because we looked at it as a national adventure, and those benefits flowed. If we started out by saying, what is the return from this mission in terms of how will it improve our economy, I do not think we ever would have gotten where we are.

Senator HEFLIN. Thank you.

[The following information was subsequently received for the record:]

QUESTIONS OF THE COMMITTEE AND THE ANSWERS THERETO

Question 1. NASA has stated that an initial operating capability for a space station is possible by 1992, if approval is given for definition studies to begin in fiscal year 1985.

a. How urgent is it that the United States have a permanent manned presence in space by 1992 and, if not by 1992, when will this need become urgent?

Answer 1. In my opinion, it is important to maintain a strong continuous civil program in manned space flight. However, it is very difficult to attach any degree of urgency to a specific date.

Question 2. What effect would the development and presence of a space station have on stimulating new science and application missions that heretofore have not been identified?

Answer 2. I do not know. I would not be surprised if there were some new missions which would come out of a broadly defined space station program, but I think a more likely event would be in doing the missions we have identified in different ways.

Senator GORTON. Thank you, Dr. Reis. We appreciate having you here.

Our next panel will be NASA itself, Mr. Beggs and Mr. Hodge. You may proceed.

STATEMENTS OF HON. JAMES M. BEGGS, ADMINISTRATOR; AND JOHN D. HODGE, DIRECTOR, SPACE STATION TASK FORCE, NASA

Mr. BEGGS. Thank you. Mr. Chairman, members of the subcommittee, I appreciate the opportunity this morning to review with you the potential development by the United States of a space station in permanent orbit around the Earth. Such a station is currently the subject of discussion within the administration, so your hearings today are both timely and welcome.

Earlier this year, President Reagan requested an interagency study to establish the basis for an administration decision on whether to proceed with development by NASA of a permanently based, manned space station. The analysis was to address issues relating to leadership in space, fulfilling mission requirements, foreign policy and national security implications, and economic impacts. The study, which took place over the spring and summer, is now complete. The space station is a major policy decision that will shape the future of our activities in space. Accordingly, it is presently under review at senior levels within the administration. No decision has yet been made.

Mr. Chairman, in your letter of invitation to appear before you today, you asked that I assess the uses of the space station. Based upon our analysis and that of our industry contractors, it is clear that a space station can serve a number of functions. Properly conceived, a station could function as: A laboratory in space for the conduct of science and the development of new technologies; a permanent observatory to look down upon the Earth and out at the universe; a transportation mode where payloads and vehicles are stationed, processed, and propelled to their destinations; a servicing facility where these payloads and vehicles are maintained and, if necessary, repaired; an assembly facility where, due to ample time on orbit and the presence of appropriate equipment, large structures are put together and checked out; a manufacturing facility where human intelligence and the servicing capability of the station combine to enhance commercial opportunities in space; and a storage depot where payloads and parts are kept in orbit for subsequent deployment.

Perhaps more important than any of these individual points, however, is that a space station, in my belief, could also lead to important activities and functions that we presently cannot even predict today. Were NASA to have a station, it would represent a fundamentally new and versatile capability to support activities in space over the next 30 years.

Mr. Chairman, your letter of invitation also requested that I comment on alternative approaches that would satisfy the requirements of a space station. Many of the functions I outlined just a moment ago could be performed by other means. Over the past 20 years, NASA has examined a broad spectrum of space station concepts. These have included both manned and unmanned configurations.

An unmanned space platform in itself, for example, could be a useful asset for space science and applications. We have studied such a platform, and have a solid understanding of its potential capabilities. Over the past several years, we have also looked at the potential for extending the time in orbit of the shuttle orbiters. Presently, we have underway a further study of the potential of an extended duration orbiter which we hope to complete soon.

The duration in orbit for Columbia and her sister ships is currently about 9 days. Analysis suggests that this can be extended to from 14 to 21 days without substantially modifying the basic orbiter design. I suspect that an extended duration orbiter is a useful project to undertake on its own merits as part of the overall space shuttle program. Going much beyond 21 days, however, might require recasting many of the orbiter's basic systems. This could require significant funding, and would produce only a modest increment of capability. Further, the capabilities of an extended duration orbiter would clearly be more limited than what a space station could provide, and I might add, Mr. Chairman, the use of a limited number of orbiters in an extended mode would limit their availability for moving back and forth and serving as transportation.

Our concept of a space station encompasses both manned space flight and unmanned spacecraft. Our experience and our intuition tell us that man has a part to play in the operation of certain ele-

ments of a space station. At the same time, we realize that under certain activities, particularly those of a routine nature or those that can be programed in advance, are better suited for automated systems.

The challenge for NASA would be to design a space station that achieves the best of both modes. We must find the proper mix of man and machine. The Soviet space station, Salyut, provides a major role for man in space. The cosmonauts perform a wide variety of tasks in terms of both monitoring and maintaining the station itself and of operating its many payloads. Salyut 7, the latest of their stations, is a genuine space station. True, it is small, and in some areas employs technology clearly inferior to our own, but manned space flight requires a base level of competence which the Soviets have clearly acquired. What concerns me about the Salyut program is not so much Salyut 7, although we should take note of payload capabilities and operational procedures the Soviets are developing with Salyut 7 and its predecessors, particularly Salyut 6, but rather what station will follow Salyut 7, what kind of a facility the cosmonauts will be occupying during the 1990's, and what exactly they will be doing in space at this time. The Soviets have said that they intend to develop a large, permanent space station. What have they learned from the Salyut program that leads to such an objective?

The national space policy announced by President Reagan in July 1982, provides a roadmap for our activities in space. The policy establishes the basic goals of our space programs which are to strengthen the security of the United States and maintain the U.S. space leadership, obtain economic and scientific benefits through the exploitation of space; expand U.S. private sector investment and involvement in civil space and space-related activities; promote international cooperative activities in the national interest; and cooperate with other nations in maintaining the freedom of space for activities which enhance the security and welfare of mankind.

I believe a space station could contribute significantly to these goals. Let me comment briefly on a few of these goals and how a space station relates to them.

Already economic benefits accrue to the United States from the exploitation of space. The communications industry is in large part space based, a dimension which is responsible for improved service at lower cost. This was made possible by Federal research to develop the initial technology and to reduce the risk to an acceptable level, thus enabling private venture capital to launch a now highly successful business enterprise. I believe a space station could do the same for the field of materials.

Mr. Chairman, one of NASA's goals is to expand opportunities for U.S. private sector investment and involvement in civil space-related activities. The space station would help us do that.

The President's national space policy reaffirms the goal of promoting international activities in space where these activities are in the national interest. This reinforces a NASA objective mandated by Congress with the passage of the Space Act in 1958. In many instances, foreign aerospace capabilities are now fully mature and competitive with those of the United States. Thus, other nations

could make genuinely significant contributions to a U.S. space station, were we to embark upon such a program. Already, several nations have indicated the desire to do so.

Any cooperative venture on a future space station would need to guard against the unwarranted transfer of U.S. technology to our competitors abroad. Markets are global, and we must not make it easier for those whose projects compete with our own to gain a competitive advantage. With care and commonsense, however, we can continue the benefits provided by international cooperation in space, yet accommodate legitimate concerns with technology transfer.

In the future, NASA hopes to increase the benefits our many activities in space provide. These activities, in science and applications, in launch vehicles, in technology, and in the area of commercial endeavors, offer tremendous potential for the years ahead. I foresee a future in which we will have on orbit large astrophysical observatories where we have over time built up a system of Earth looking imaging systems where a stable planetary program results in periodic missions, and where commercial endeavors in space are significant in both number and benefit.

Such a future could reflect an infrastructure with the following characteristics: The ability to assemble large structures; improved transportation from low-Earth orbit to geosynchronous orbit; on orbit flexibility in maintenance and repair; suitable accommodations for living and working in space; and removal of the mystique associated with manned space flight. These are the characteristics or capabilities associated with a potential future space station. In the long run, a space station would help establish this infrastructure and preserve future options for a truly new national endeavor in space. It will be a stepping stone to future space exploration.

Mr. Chairman, that concludes my brief summary. We would be pleased to take questions.

Senator GORTON. Mr. Hodge?

Mr. HODGE. Thank you, sir, for the opportunity. I do have a statement for the record, but I would like to make a few points before we go ahead with the questions.

Senator GORTON. Your statement will be included in the record as if read. We would appreciate your summarizing.

Mr. HODGE. Thank you, sir.

I would like to just reinforce some of the statements that have been made this morning, that in discussing the space station program we are not talking about a single entity. We are talking about a mixture of manned and unmanned elements (fig. 1). We are calling the base the manned part of it, and it has the normal functions you would expect—somewhere to live, somewhere to do laboratory functions, somewhere to berth, and so on. That is what, characteristically in the past, has been called the space station. Associated with that, and very importantly, are a cluster of unmanned elements where we do those things that are more appropriate to be done without the man being present.

For example, sometimes it is inappropriate from a contamination standpoint and sometimes it is inappropriate from a microgravity standpoint to have a man around. Nevertheless, if we have these unmanned satellites close by to the manned element, then we are

able to take advantage of changing out the instruments and servicing the platforms on a continuous basis.

Now, when you have the system in such a low Earth orbit, what you have to do is be able to move backward and forward between the manned elements and the unmanned elements. So we have included in the program conceptually maneuvering units. We have called them orbital maneuvering units—and then either with straight EVA, having the man outside and working on the system, or potentially with tethered systems to the manned element.

The interesting part about this architecture is that you can add to it. You can expand the system over a period of time as the market develops or as you require more and more capabilities. You can add more laboratory elements or more unmanned satellites. In addition to that, you can add, at a later time, the ability to use the manned element as a transportation node. There is no question that eventually we are going to want to go beyond the low Earth orbit system in a more efficient way. Some of the studies we have done have shown that if we space base the upper stages instead of taking them up and down from the Earth continuously, that there are significant economies to be gained from having an upper stage permanently based in orbit.

Dr. Reis said earlier that if you take any single function for a space station and then try to justify it on a cost-benefit basis, you can probably do each single element in a cheaper way in an unmanned system. The beauty of a manned station or the system we are describing here is that as the total number of things to be done increases, then it becomes more and more beneficial to have this kind of system. It really is a question of determining how far things are going to go in the next 20 or 30 years rather than taking each single function.

What we have decided as we have done the study is that the space station really only makes sense if you plan it first of all in an evolutionary way, so that it will grow in capability with time, but so that it also has multiple functions. What I have tried to indicate here on figure 2 are the kinds of functions that we really see being performed on the space station, not necessarily all in the first instance, but built in such a way that we can eventually grow to all of these capabilities.

Another problem we have had is the continual discussion about whether or not a system should be manned or unmanned (fig. 3). As I mentioned earlier, there are certain cases where it is absolutely essential that no man be present, and particularly in some of the scientific instruments where it is necessary to keep the contamination levels down to a very low level.

Nevertheless, there are things that man can do, and we have seen them in the past in the Skylab program and the Apollo program. There is no question that we have to develop our robotics and our automation capabilities in time; and, I think that one of the things that this program will do will provide a focus for improving our capabilities in those areas.

The trick in designing the space station is going to be to select the proper mix between man and machine. I think they are both required. I think we need a combination of manned and unmanned

elements, and the judgment of deciding how much of each in the program is what we are about.

One of the important things about putting this program together is to clearly define (fig. 4) what it is we want to do before we go ahead with the design stage and before we start to build hardware.

NASA, at the request of Congress several years ago, did a study on how to reduce the cost of space programs. There was one clear result from that study, and that was that it is worthwhile spending more money up front during the definition phase before commencing hardware in order to maintain the cost and keep the specifications constant during that period. We really believe that we should spend an extended period of time and a significant amount of money, 5 to 10 percent of the initial cost of the program, in order to maintain the costs during the production phase.

One of the real problems we have had with designs in the past is that we have let the contract for the hardware before we have had very clear specifications. The other problem you have in the management sense is that people are always willing to do something a little bit better. NASA is a very success oriented organization, and it really wants to make sure that everything works in the best possible way. The trick to maintaining the cost of the program during the manufacturing stage is to decide what you want to do exactly before you go ahead.

Now, if you can keep the technological risk down and the specifications well in hand, then you can keep the cost of the overall program down. One of the neat things about the space station program is that we can decide to build it in increments. If, in fact, somebody does come up with a better idea during the early manufacturing stage, you can always postpone that to the second increment. It is by that process I think that we can keep the costs down significantly.

We have, in addition to looking at this concept of extending the definition of the program, worked very hard in the last year to involve the potential users of the space station. We really believe that it is important that the customers, whether they be commercial or scientific, or whether it be the national security people, be involved very extensively in the early design.

In that way, we can make the design user friendly. We can make it easy to get into space. And I think we can enhance our commercial capability in time.

To give you a feeling for what we have been doing since we put the task force together in May of last year, we spent the first year looking very carefully at mission requirements (fig. 5). We then took those mission requirements and said: "What kind of functional capability do you need in order to satisfy those potential mission requirements?"

And then we had to look at the kinds of technologies that would be available in this timeframe to see if any of them were missing and what sort of technological program we should have in order to give us the options we would need as we move into the 1990's. And then we put a small systems engineering group together to trade off those things against each other. We have now gone through this process a couple of times in the last year and a half.

We are beginning to reach the stage where we believe we can make some definitive decisions about the design and configuration of the system. We have assiduously avoided specific configurations to date, because there are still lots of good ideas out there, and we want to insure that we understand them before we go ahead with configurations.

It is with some trepidation I would like to show you figure 6, which is the indication of the sort of configuration we think that we will be looking at in the early 1990's—a relatively modest system with two or three laboratories, and the ability to service satellites. The system as we see it right now needs to be power rich. If the commercial products develop in the way that Mr. Wood was talking about this morning, then we are going to need a large amount of power in that timeframe, and we are talking about significant power.

The important thing about the definition that we are describing here is that we should really look to the future and design the future system at least conceptually before we commit to the early pieces. That will enable us to build with time and make those incremental decisions during the period of the 1990's. So, we have, in addition to looking at the early stages, looked at the system that we think will be around toward the end of the century. Essentially what you have is a system that is composed of the same elements that were there in the beginning, but we simply increase the size of it. The system as we see it for the period 2000 is about double the size, figure 7.

Just to put those into figures, we see at the moment the need for a system, figure 8, that has six to eight people in the early 1990's and significant amounts of power, and I should say that 75 kilowatts is equivalent to just about all of the power that NASA has put up on all of its programs to date. So, it is a lot of power. But these commercial products do require significant amounts of power. We would have the orbital maneuvering vehicle, which we are looking at as an adjunct to the orbiter right now. Then, of course, we have to have a logistics module which will take the resupply systems backward and forward to the space station on a regular basis. We are talking about 90-day intervals. And, associated with that would be two platforms, one at 28.5 degrees, where most of the commercial work would be done, and a polar orbiting platform which would be associated with Earth viewing, Earth resources type instrumentation. And as you can see when you look toward the end of the century, we have a system which is more or less twice that size.

That is all I have for now, sir. Thank you. I will be glad to answer some questions.

Senator GORTON. Thank you very much, Mr. Hodge.

Eight aerospace firms have performed space station mission analysis studies for NASA to identify the user needs of the space station. They have come up, as I understand it, with more than 100 missions. To what extent do these missions require a permanent manned presence in space, and in what other conditions is a permanent presence more desirable than intermittent presence?

Mr. HODGE. It really varies from mission to mission. For example, the astrophysics science instruments, which are really tele-

scopes that are looking outwards. In that particular case, it would be suitable to put them on a free-flying satellite or a platform where you put more than one instrument. But from time to time you would need to modify that instrumentation, to repair those systems, and in some cases, like an infrared telescope, you need to replace the cryogenics. In that case, you are looking at occasional visits, perhaps once every 2 or 3 months, to a system of that kind.

You get into other parts where continuous manned presence is required. For example, in the general business of maintaining and repairing satellites, we believe that there will be a sufficient number of them there that you can maintain a repair capability continuously on orbit with a manned system. In the business of the development of technologies, what we have called the Langley Research Center in Space, where you are actually doing research on new technologies continuously, then it really is advantageous to have them there all the time.

In the case of life sciences, I think Dr. Reis said there we are looking for very, very long periods of zero G, and it would be useful to do that. So it really is a question of the agglomeration of various things that you want to do that drives you to this situation of saying that it is advantageous to have a man there permanently.

Senator GORTON. Jim, you spoke to the fact that NASA has considered alternatives to a permanent manned space station. You discussed at least generally in your testimony a platform and a shuttle with longer capabilities. Is that an exclusive listing of the alternatives which NASA has looked at?

Mr. BEGGS. Oh, no, sir, we have looked at any number of different options, including all different kinds of platforms. We have some platforms which are operational now. We flew what is a rudimentary platform in STS-7, which was designed by the Germans, called SPAS-O1, which could sustain a certain number of experiments. We have studied very large sophisticated platforms which would contain a multitude of different instruments or even commercial processing activities.

We have looked at space stations in various configurations from very large to very small. We have looked at the orbiter extended for beyond the 21 days, as I mentioned in my statement. Beyond 21 days, it starts to get very expensive, and you get into the initial problem that if you are going to extend the stay time of the orbiter for very long stay times, then you are going to need a number of additional orbiters.

In short, we have considered a broad gamut of different things. Space stations and space platforms have been under study in NASA for really over 25 years. Historically, the first examination of a space station option was during the planning for the Apollo program, which Dr. Werner Von Braun and a number of other visionaries in the program at that time urged that we go to the Moon by an Earth orbital space station, and indeed that was one of the options considered for the Apollo program.

It was decided at that time that it would take too long to do that, and since our commitment was to go to the Moon within the decade, we abandoned that approach and went to the lunar orbit landing technique. But there has been—the NASA files are literally crammed with material on various alternatives to put a perma-

nent presence in near Earth orbit, and the alternatives to doing that in various ways.

Senator GORTON. Mr. Hodge, how does this concept of an initial space station which you showed us on one of your slides compare in size, capacity, and sophistication with Salyut 7, and what you expect the Soviet Union to be doing during the course of the next decade.

Mr. HODGE. In size, if you want to talk about it in terms of internal volume, it is about the same size. In power, it would be significantly higher than that, and of course the concept that I have there includes both the manned and the unmanned satellites working with each other, and that is quite different than what we see them doing at the moment. I really am not in a position to predict what they are going to be doing by 1990.

Senator GORTON. In sophistication and the kind of activities in which it can engage, what would a comparison be?

Mr. HODGE. I think that will vary with the technology that we are talking about. They have an automatic rendezvous capability at the moment which we do not have, but it is not essential in the concept that we have put together. But I think with regard to computational capabilities, sophistication of instrumentation and so on, we will continue to lead, as we have done for the last 20 years.

Mr. BEGGS. Mr. Chairman, while we cannot predict what the Soviets will do in the next 10 years, we can make one prediction, and that is that they will continue to advance in this area, because they have developed step by step in the last 10 years. They fly a lot. And we can anticipate that they will continue to fly.

We know that they have announced they are developing very heavy lift launch vehicles, so you can anticipate that they will expand their capability in the space station area, because they have been expanding it for the last 10 years, and they have announced that they intend to expand it for the coming 10 years. Their technology, as John suggested, is significantly behind ours in sophistication and capability, but they do grow step by step, and they have become much more capable in the last 5 years as they have been flying regularly in operating long duration and in doing more sophisticated experiments and being able to do repair work in space.

Senator GORTON. You have indicated that during the third year of definition studies, NASA would like to begin the development of the space station. This would be about fiscal year 1987, with its initial operating capacity to begin in 1992. Is that simply the earliest date at which you can be operational, given the state of the decisionmaking process now, or is there another reason for a 1992 goal?

Mr. BEGGS. No. The date we chose is simply putting down on paper what we considered a very orderly program. You could crash this program or accelerate it in various ways and get a capability sooner. All of us, as we reviewed the history of the agency, that it had in its other manned activities, that we would be well advised to do this on a staged program.

Several of your witnesses have suggested that there is no great urgency, and I would agree in part with that. There is no great urgency in the sense that we need that capability immediately. There is a sense of urgency that if we do not begin at some point, you

never get there, and we feel that in taking the 2 years to define the program very carefully, we will obviate some of the problems we have had in previous programs, where we have begun on a hardware program before we have fully defined our concept and our systems, and as a consequence of that, have had to backtrack and redo certain work.

By taking that 2 years, I think we can fully define and specify what it is we want to buy in terms of hardware and software when we start to buy it, and therefore do the program in a rational and the most economical way. The 1992 date or 1991 date—1992 is a nice historical date, but other than that, it is a rational and logical amount of time to do the construction work and get it done in the most economical way.

Senator GORTON. Finally, Dr. Reis made the point that it is unlikely that we can use an accounting system of cost-benefit analysis and come out with a narrow justification for a space station on that basis, but that the decision is in the broadest sense essentially a political one. It has to do with our vision of ourselves as Americans and our position in the world, and for that matter the relationship between NASA and the American constituency which it represents.

Would you comment on that attitude, that perception of this problem? Do you agree with it or not?

Mr. BEGGS. I agree with Vic Reis in that analysis, but I would argue a little bit that you cannot make an economic cost-benefit analysis. The plain facts are that one can project economic benefit. You may not believe it, because it is projecting benefits which will occur through the research and development that you intend to do in order to establish this capability, but you can clearly establish the relationship of our past programs on an economic cost-benefit basis.

We have had a number of studies by the most prestigious economic concerns in the United States, and they indicate that the returns on our past R&D, both in the manned and unmanned period, have yielded benefits that are in the order of 20 to 30 percent per annum, and I believe that. That return is a large benefit because since we started out our adventure in space in 1958, we have spent about \$95 billion, which is a large sum of money. When looked at, however, in relation to the total amount of money that the Federal Government has spent in that same 25 years, it is about 1 percent. But, we have, we believe, and we are sustained by folks in the private sector who have done studies on it, yielded a benefit to the United States of 20 to 30 percent per year on that investment.

I think a similar return, if not more, will be generated by an investment in the future including a space station. But there is, if you will, a bit of faith in those projections, because what it says is that what has happened in the past will indeed again happen in the future. I happen to be, as you know, Mr. Chairman, a firm believer in investments in research and technology in this country, and therefore I believe those benefits will continue to flow.

Senator GORTON. Thank you.

Senator Heflin?

Senator HEFLIN. Mr. Beggs, what opportunities could a manned space station offer which could not be performed by an extended duration orbiter operating with an unmanned space platform?

Mr. BEGGS. May I comment just for a moment, and then ask John to add what he would like? The presence of human intelligence, we have found, is extraordinarily important in several areas. First is the question of being able to repair, modify, and work with instruments in space so as to get them up to their full efficiency.

The first of the very complex scientific instruments which will be put in space and tended by man in that sense will be the large space telescope which we will launch in 1986. The large space telescope is designed so that it can be tended, so that it can be repaired, modified, and occasionally visited, and the human intelligence can be applied to make it work to its full efficiency. It is intended to be tended right now by the shuttle from time to time, but it would be much more efficient if it were flying in concert with a manned space station where you could go over when it needed tending and tend it.

Second, there is the very important experimentation that one does that requires human intelligence in order to get the important feedback mechanism operating where you learn, if you will, as you go along. At the end of this month, we will fly the first flight of the Spacelab, which, as you know, Judge Heflin, is the laboratory designed by the Europeans for the space shuttle program. We will fly that laboratory to the extent of our current mission capability on the shuttle, 9 days.

We will take up scientists who will work in the laboratory on experiments, and as they work, they will learn, but you have to remember it is only a short period of time. We believe the ability to extend that time for experimentation in space, in short, to do as John Hodge suggested before, have a Langley Research Center in space, where they can continually develop the experiments and continue to learn from the experiments is an extremely important capability.

Then, of course, there is the ability to apply human intelligence to observing what is happening in real time. That is, to look at the Earth and to look out at the solar system, the Sun and the universe, and to acquire the data and apply human intelligence to it in real time, and then send the data perhaps down to Earth for further analysis. The ability to do that, we think, can make those observations a great deal more efficient. How much more efficient, it is hard to say, but a great deal more efficient. So, there are a number of things.

And then, of course, we envision that in the long term we will be able to go out and bring satellites to the station and store spare parts on the station so that we can repair them on orbit and perhaps, you know, as time goes on, and new instruments of greater capability become available, to replace some of the equipment with new, more modern equipment. It is hard to think of one of our satellites that we do not spend on the order of \$100 million to design and produce. We are talking about a very large asset, a very large resource which, if we can extend its life and extend its capability, yields a very large cost benefit. Do you want to add anything?

Mr. HODGE. There are a couple more functions which I think are enabled by the manned space station. One of them is the construction of very large objects. We are seeing more and more as we look to the future a need for things which are considerably larger in physical size, not necessarily weight, than we can take up in the shuttle or with an expendable launch vehicle at the moment. A typical example very large diameter apertures for telescopes. People are now talking about building things of 30 meters or 100 meters or 200 meters. They need to be constructed in situ, and it is very difficult when they get to be very large to erect them in the way that we do now—deploy them is the word we use now, where they have to be automatically deployed. When they get to be very large, it is much simpler to do it with a man in place there, to actually build it in situ, so there is the whole question of construction.

The other one is the use of the space station as a transportation node, a place to base the upper stages. Instead of taking them backward and forward from the Earth, you save that extra energy, and you can base an upper stage in orbit and never bring it back to Earth. At least you bring it back perhaps every 10 or 12 flights. So, there are two more in addition to the ones that Jim was talking about.

Of course, in the life sciences area, you could say in some respects that is sort of self-serving, because the purpose of the life sciences lab in many respects is to find out how man operates in space. But you certainly cannot do that in timeframes of 10 or 20 or 30 days. You are looking at biological mechanisms which take months and months to occur, and you need that long duration of zero G in order to study them properly. And, let us face it, if we ever want to go to Mars, that is a 25-month journey. We will need to understand those things.

Senator HEFLIN. Would I be correct in making the statement that without the presence of human intelligence in a laboratory or in a manufacturing facility, then you have most unusual problems?

Mr. HODGE. Yes; I think so. Peter Wood was saying earlier on that they have looked at the business of automatic factories on the ground, for example. Even the simplest of our factories on the ground that are so-called fully automatic have some kind of a tending system there. Perhaps the simplest one is to say the production of fertilizers, where you mix things together and just stir like in a cookbook, and it is totally automatic, and they just shove out bags of fertilizer at the end. They have at least one manned intervention per shift.

Senator HEFLIN. You have to have a cook in the kitchen.

Mr. HODGE. That is the sort of thing, yes. It is very difficult to build something which will continue to operate for very long periods of time without some kind of intervention. And what we have done in the past with our spacecraft, in order to get around that problem, is to provide large amounts of redundancy, very sophisticated instrumentation, and very sophisticated communications and command paths so that we can do that from a control center on the ground.

What we have done, really in many respects, is to put the man on the ground at great expense in order to do that. The tradeoff we

have to make is, where do you put man in the system? Is it cheaper to put him on orbit where he can do things quickly? Or do you want to go to the sophistication of the rest of the stuff and put him on the ground? And it is that kind of a tradeoff which you have to make. There are very few people who can tell you we can do these things without manned intervention. The real question is, where do you put the man? And, what we are showing is that in a number of circumstances it is advantageous to have him there in orbit.

Senator HEFLIN. Let me ask you this. Why not start with an unmanned platform and evolve to a habitable facility? What are the advantages and disadvantages of an evolution starting with unmanned and then evolving to a habitable facility?

Mr. BEGGS. It is an alternative. It is a way you can go. And, we will be flying some unmanned platforms in the next several years. There are several being developed privately, in cooperation with us, which will fly from time to time in the shuttle or independently from time to time. Our view on that is that, as Mr. Hodge showed in the slide, to make an unmanned platform truly totally productive, it should be flown in conjunction with the presence of human intelligence.

Since we are looking at a capability that we will not have, even if we initiate it very soon, until the early 1990's, we think that this is the time to start developing a manned capability. As you develop a manned capability, it would also suggest, I expect, that there are ways to improve the use of the unmanned elements of it. In short, the program hangs together, just as all the pieces and parts of the space program have tended to contribute one to the other over the last 25 years.

Senator HEFLIN. Will a space station program create a requirement for additional space shuttle orbiters?

Mr. BEGGS. Not in and of itself, No, sir. It is my view that at some time in the next several years, that we probably will construct at least another orbiter, but the space station requirement does not overload the current system.

Senator HEFLIN. Would an extended duration orbiter capability within the existing fleet create a need for an additional orbiter?

Mr. BEGGS. Very likely, yes, sir. It would again depend on how many times you wanted to exercise that extended capability. If you exercise it more than a few times a year, then, clearly you would need another orbiter. Our current calculations for the current fleet of four, of which we have three now delivered, is that we expect to fly each one eight times a year.

Eight times four is thirty-two, and our current projection is to go up to 24. Our current projections are based on the fact that we will probably have, at any given time, one orbiter laid up for overhaul or for modification for a number of reasons, and that, indeed, is proving true so far. So, we will operate 3 orbiters 8 times a year to reach the 24 per year capability, which is what we are projecting as the initial plateau of capability.

So, you can see that with 8 times a year, we are turning them around better than once every 2 months, about once every 6 weeks. If you extend the stay time to 3 weeks in orbit, then the turn-

around rate becomes very, very difficult. So you would probably need another one to do that.

Senator HEFLIN. You testified that the space station would be a stepping stone to future space exploration. What characteristics of a space station enables such space exploration?

Mr. BEGGS. The ability to stage from Earth orbit instead of from the Earth. It has been described as a transportation node. I used that term in my statement. And indeed it is. Eventually, you can start to take your pieces and parts up and assemble them in orbit, marry them with an upper stage in low Earth orbit, and then fly them to wherever you want to fly them. That is a much more efficient way of operating than to stage the whole thing from the Earth's surface. The energy requirements are much less, and the ability to do more versatile and complex things is enhanced significantly. Do you want to add to that?

Mr. HODGE. Just a little, perhaps. We have looked at several potential things that we might likely want to do in the 20- to 50-year timeframe—they are really rather obvious. You might want to go back to the Moon and set up a permanent base there. You might want to go to Mars, to land on Mars, or to just simply take samples from Mars. You might want to visit some asteroids. There are some rather interesting things on some of the asteroids, very high purity ores, for example.

But as you look at the way you would do that in an orbital mechanics way and you look to all those potential futures every one of those futures would require some form of construction base and transportation node, which is a perfectly good description of a space station. So, by building a manned space station, what you have is the alternative to select a number of futures without having to make the specifics of that future so definitive at this time that we would not want to do that, and to keep the future options open.

Senator HEFLIN. If we develop a much more accelerated propulsion system for spacecraft, will a space station still assist in this exploration, as a stepping stone?

Mr. HODGE. We need to examine the kinds of technologies we are talking about here. At the moment, the best we can do is hydrogen-oxygen system. One of the useful things about using the space station as a transportation node is that if we use a hydrogen-oxygen engine, that we can take that hydrogen-oxygen up from the ground in the shuttle, what we call on the margin. The reason for that is that the shuttle tends to fill up before it runs out of performance. The size of the spacecraft tends to be such that you have got plenty of weight to spare in the shuttle. The shuttle is at the moment, and I think for the next 2 or 3 years, working at about 65 percent of its weight performance, even though the amount of length used may be greater. That means that you can take up in the residual weight-length capacity the hydrogen-oxygen more or less for free. You take it up at the cost that it is on the ground, and that really enables us to go to much higher energy orbits at a lower cost. At least that is the theory behind it. We need to test that some more.

When you go toward more sophisticated systems, like electric propulsion systems, my guess is that the way you would reduce those is such that you would want to have on orbit assembly of the

systems, and some kind of permanent facility to do on orbit assembly would be useful. I am speculating somewhat there.

Senator HEFLIN. President Reagan announced his space policy goals in a speech on July 4, 1982. It was a good speech. One of his goals was to maintain U.S. space leadership. How can we not have a space station if we are to meet this goal of maintaining U.S. leadership?

Mr. BEGGS. I think the leadership role really relates most importantly to what the Soviets are doing. It is true that the Soviets are developing a space station. That has been clear for the last 5 years. And in the sense of a competitive situation vis-a-vis the Soviets, it would be clear that a space station capability on the part of the United States is necessary in order to maintain one's competitive posture with the Soviets. However, we have to allow that. That is not the total spectrum of things that will be done.

We do a lot more sophisticated work than the Soviets both in the planetary area and in the science area, and I think we will continue to maintain that part of the lead. It is a fairly complex equation that you are looking at when you compare leadership in this field. The Soviets tend to march to a different drumbeat than we do. They have chosen to develop their space station early. We chose to develop the shuttle early. I think we still lead in this race by a significant margin with the strategy we adopted.

The crystal ball is always a little cloudy as to what it might look like 10 or 15 years from now, but the view that NASA has at the present time, looking into that crystal ball, is that we should, indeed, go on to develop the next logical step, that is, the space station capability, or if not a space station capability, then certainly a very sophisticated space platform capability to marry it with the shuttle. But, our current view is that the space station buys you the most, both in terms of capability and in terms of the overall economy of operation of the system.

Senator HEFLIN. One last question. Could you comment, if you can, on the Soviet space station and its military use?

Mr. BEGGS. I can tell you what has appeared around the world in press accounts which, without, I think, transgressing on any security activities. They have used their space station for a lot of the same things that we have talked about here. There has been a long-term program in materials processing underway in their space station. We know that they have used it for that purpose. We also know that they have used it from time to time for Earth observation because they have announced that they have.

They have talked about the experiments that they have run, and they have used it to exercise their cosmonauts in a number of different operations, improving their capability to operate. There has been a lot of extravehicular activity going on outside. They have worked on the spacecraft and have proven, in short, that they can repair on orbit, and that repair activity does have a military bearing as well as a civil bearing. The ability to repair in orbit is important activity.

It was widely reported in the world's press about a year ago that their space station participated in some military exercises, and I expect that just as one would conjecture with having men in operation on the high ground, if you will, the kind of thing that Gener-

al Graham has talked about in his published studies, that they would use it in the command and control function in that process.

So, I expect they are experimenting in trying to see the usefulness of it in actual military operations. How useful it has been it is impossible to judge, except a conjecture.

Senator GORTON. Senator Tribble?

Senator TRIBBLE. Thank you, Mr. Chairman.

Gentlemen, given President Reagan's statement on October 19 about pursuing a more visionary space policy rather than simply taking the next step, what should NASA be doing in concert with a space station program and as a followup to that kind of program?

Mr. BEGGS. We can, I guess, give you as much vision as you can stand.

Senator TRIBBLE. I thought you would welcome that opportunity.

Mr. BEGGS. We have looked over our 25-year history and the many studies that have been done in the past to try to project into the future. There have been many, many, many programs which project out, if you want to go out that far, for 100 years. Dr. Von Braun had a series of studies done while he was working in this field. As you know, Werner came into Washington in the latter stages of the Apollo program, and became our chief planner within the agency.

Dr. Von Braun has a whole series of writings which are in the files, which project return to the Moon with a base, expansion of that base into the use of the Moon's resources and the use of the Moon as a scientific base for observations of various types. Of course, his great dream was to go on from the base on the Moon to a manned flight to Mars, a Mars orbiter, and eventually hopefully a lander on Mars.

The potential of large, sophisticated astronomical observatories either on the Moon or in higher Earth orbit to observe the universe closer and perhaps get a better insight into how the universe is growing and developing, and maybe how even—the question of how it began and how it might end, and all of the age-old mysteries, which, incidentally, probably have very significant benefits back here on Earth. If you can define how the universe works completely, you can come up with a unified theory that Dr. Einstein was working on when he died which would have an immense impact on life here on Earth.

The ability to observe the Earth in a very sophisticated way, which we have done a number of studies on and which goes under the name currently in the agency of global habitability. In other words, designing and operation of a system that would enable us to observe the Earth over long periods of time and really start to understand the human effects on our environment as well as the natural effects on the environment and to study the Sun cycles over long periods of time. We are learning now from the studies that we have already done on this medium-sized star we call the Sun, that its cycles have a very direct effect on weather. The short cycles of the Sun can be correlated very directly with the short-term weather cycles, so we suspect that the long-term Sun cycles have a long-term effect on the long-term weather, climatic changes on the Earth. So that is an interesting long-term study.

Through the continued study of our solar system and the studies of comparative climatology, we know that there are very strange and mysterious things on the neighboring planets. Mars, for example, has an erosion canyon running down it six times longer and three times deeper than the Grand Canyon in Colorado, and locked into that canyon is probably the long-term geologic history of the solar system.

We will be going back to the outer planets, the primordial planets—Jupiter in 1986 with the Galileo probe, which will be an orbiter and a probe into the Jovian atmosphere. This will be our first opportunity to observe and study at close range the primordial material from which the solar system was created.

Mr. Hodge has mentioned the possible visit and maybe economic use of an asteroid or series of asteroids, and the ability to study comets and cometary material. All those things can be fitted into a long-term plan which you can extend as far out as you want to go. Someone characterized this program as the endless frontier, and indeed it is. It goes on forever, because there are so many opportunities to expand the human knowledge into the cosmos that it is neverending. And we do have plans laid down like that. We can bring them out of the files at a moment's notice, because they all have been written and carefully put together so that they extend out for any period of time that you want.

The problem that this agency has had over its history has not been a lack of vision or even a lack of planning. We always have more on our plate than we can afford. We always have more programs than we can fund. The problem has been to get a commitment in long enough increments so that we can work them and plan in a logical orderly fashion, and so accomplish all of these things in concert.

The complaints that our scientists have, and I have read Dr. Donahue's statement here, has been that: "Gee whiz, the funding goes up and down." But, he makes one very significant point in his testimony, and that is that the space sciences, the unmanned space sciences, and our support of the scientists and researchers has been a pretty constant percentage of our budget over the history of the agency. The problem is that the budget has gone up and down, and as a consequence their budget has gone up and down. But we have always devoted about the same percentage of our resources to each of the areas of investigation. So the plan has been developed and consummated in concert.

The problem has been that our long-range planning has always been interrupted by the fact that for one reason or another we did not have enough dollars in one given year to sustain everybody at the level to which they would like to become accustomed to operating.

Senator TRIBLE. Thank you, Mr. Beggs.

Thank you, Mr. Chairman.

Senator GORTON. I would like to thank both of you, and to say that it is likely that we will submit some questions in writing to each of you as well. Thank you.

[The statements and answers to questions of the committee follows:]

STATEMENT OF JAMES M. BEGGS, ADMINISTRATOR, NASA

Mr. Chairman and Members of the Subcommittee: I appreciate the opportunity this morning to review with you the potential development by the United States of a space station in permanent orbit around the earth. Such a station is currently the subject of discussion within the Administration, so your hearings today are both timely and welcome.

For the past eighteen months, following the successful flights of the Space Shuttle, NASA has conducted preliminary definition efforts in support of future decisions regarding a space station program. These efforts are relatively modest in scope and will be presented to you by Mr. John Hodge, the Director of NASA's Space Station Task Force.

Earlier this year, President Reagan requested an interagency study to establish the basis for an Administration decision on whether to proceed with development by NASA of a permanently-based, manned space station. The analysis was to address issues relating to leadership in space, fulfilling mission requirements, foreign policy and national security implications, and economic impacts. Participating in the study were NASA, the Department of Commerce, the Department of State, the Department of Defense, the Arms Control and Disarmament Agency, and the Office of Science and Technology Policy. The study, which took place over the spring and summer, is now complete. A space station is a major policy decision that will shape the future of our activities in space. Accordingly, it is presently under review at senior levels within the Administration. No decision has yet been made.

Mr. Chairman, in your letter of invitation to appear before you today, you asked that I assess the uses of a space station. Based upon our own analysis and that of our industry contractors, it is clear that a space station could serve a number of functions. Properly conceived, a station could function as:

- a laboratory in space, for the conduct of science and the development of new technologies;
- a permanent observatory, to look down upon the Earth and out at the universe;
- a transportation node where payloads and vehicles are stationed, processed and propelled to their destinations;
- a servicing facility, where these payloads and vehicles are maintained and if necessary repaired;
- an assembly facility where, due to ample time on orbit and the presence of appropriate equipment, large structures are put together and checked out;
- a manufacturing facility where human intelligence and the servicing capability of the station combine to enhance commercial opportunities in space; and
- a storage depot where payloads and parts are kept on orbit for subsequent deployment.

Perhaps more important than any of these individual points, however, is my belief that a space station could also lead to important activities and functions that we presently can not even predict today. Were NASA to have a station, it could represent a fundamentally new and versatile capability to support activities in space over the next thirty years.

Mr. Chairman, your letter of invitation also requested that I comment on alternative approaches that would satisfy the requirements of a space station.

Many of the functions of a potential space station, I outlined just a moment ago, could be performed by other means. Over the past twenty years, NASA has examined a broad spectrum of space station concepts. These have included both manned and unmanned configurations. An unmanned space platform in itself, for example, could be a useful asset for space science and applications. We have studied such a platform and have a solid understanding of its potential capabilities.

Over the past several years, we have also looked at the potential for extending the time on orbit of the Shuttle orbiters. Presently, we have underway a further study of the potential of an extended duration orbiter which we hope to complete soon. The duration on orbit for Columbia and her sister ships is currently about nine days. Analysis suggests that this can be extended to about 14-21 days without substantially modifying the basic orbiter design. I suspect that an extended duration orbiter is a useful project to undertake, on its own merits, as part of the overall Space Shuttle program. Going much beyond 21 days, however, might require recasting many of the orbiter's basic systems. This could require significant funding and would produce only a modest increment of capability. Thirty days of stay-time would be a valuable addition to the Shuttle's capabilities and there is no doubt that we could devise new and useful projects to take advantage of it. However, the capabilities of an extended duration orbiter would clearly be more limited than what a space station would provide.

At this point, it might be appropriate to comment conceptually on what NASA has in mind when we talk about a space station. I say "conceptually" because we do not have a space station design. You may have seen some illustrations of a station, and while these are nice pictures, they do not represent a NASA configuration. A space station is conceived as a multi-purpose, permanent facility in low-earth orbit, comprising both manned and unmanned elements, that significantly enhances the efficiency of our operations in space. The station could consist of a manned base and associated unmanned platforms. These platforms, there might be only one to start with, would be discipline oriented and be tended from the base by a Orbital Maneuvering Vehicle (OMV) or by astronauts conducting Extra Vehicular Activity (EVA). A tether could also possibly be employed.

The base, as currently conceived, is a cluster of functionally oriented modules. The key elements as we presently define them—and I hasten to add that these elements, as well as costs, may change as our thinking progresses—include a utility module to provide essential services such as power and thermal management to the cluster, a berthing and assembly module, a module for living and a laboratory module for working, a logistics module for supply and replenishment, and pallets or platforms to which are attached scientific instruments and repair equipment for both the base and the platforms. The base would be tended by the Space Shuttle.

The space station could be conceived from the start as a system that could evolve into a more capable system. NASA would propose that the first phase be useful in its own right, but it would be relatively small, costing approximately \$8.0 billion through 1991 when the station would become operational. Later, as requirements emerge and funds permit, the station could—if the country wished—expand into something more capable.

Our concept of a space station encompasses both manned space flight and unmanned spacecraft. The station would employ astronauts in tasks and roles where the presence of man is uniquely valuable. Our experience and our intuition tell us that man has a part to play in the operation of certain elements of a space station. At the same time, we realize that under some circumstances certain activities, particularly those of a routine nature or those that can be programmed in advance, are better suited for automated systems. The challenge for NASA would be to design a space station that achieves the best of both modes. We must find the proper mix of man and machine.

The Soviet space station, Salyut, provides a major role for man in space. The cosmonauts perform a wide variety of tasks—in terms of both monitoring and maintaining the station itself and of operating its many payloads.

The Salyut now in orbit is the seventh in a series of stations, the first of which was launched in 1971. At an altitude of some 175 miles and an orbital inclination of 52°, the station orbits the earth every 91 minutes overflying the United States five or six times a day.

Salyut 7 is a genuine space station. True, it is small and in some areas employs technology clearly inferior to our own. But manned space flight requires a base level of competence which the Soviets have clearly acquired.

What concerns me about the Salyut program is not so much Salyut 7, although we should take notice of the payload capabilities and operational procedures the Soviets are developing with Salyut 7 and its predecessors, particularly Salyut 6, but rather what station will follow Salyut 7, what kind of facility the cosmonauts will be occupying during the 1990's, and what exactly will they be doing in space at this time. The Soviets have said that they intend to develop a large, permanent space station. What have they learned from the Salyut program that leads to such an objective?

The National Space Policy announced by President Reagan in July 1982, provides a road map for our activities in space. The policy establishes the basic goals of our space programs, which are to:

- Strengthen the security of the United States;
- Maintain United States space leadership;
- Obtain economic and scientific benefits through the exploitation of space;
- Expand United States private sector investment and involvement in civil space and space related activities;
- Promote international cooperative activities in the national interest; and
- Cooperate with other nations in maintaining the freedom of space for activities which enhance the security and welfare of mankind.

I believe a space station could contribute significantly to these goals.

Civil leadership in space means preeminence in space technology, preeminence in manned space operations and preeminence in space science and applications. At a time when U.S. leadership is at issue in certain disciplines of science and in a

number of industries, our preeminence in space is a welcome and reassuring reminder of our capacity to lead. It is my belief that a space station could represent a factor in the preservation of civil leadership in space during the 1990's.

Already economic benefits accrue to the United States from the exploitation of space. The communications industry is in large part space-based, which is responsible for improved service at lower cost. This was made possible by Federal research to develop the initial technology, to reduce the risk to an acceptable level thus enabling private venture capital to launch a now highly successful business enterprise. I believe a space station could do the same for the field of materials.

Benefits to the United States also accrue from the science we conduct in space. Knowledge of the earth and a greater understanding of our own solar system and the many galaxies of the universe result from the scientific spacecraft we have placed in orbit and sent out to our sister planets. A space station could be a valuable addition to the Nation's scientific assets. A space station could enhance space science and applications by providing for the continuous operation of scientific equipment, with extensive interaction with man where that is desirable and with intermittent interaction with man where his continuous presence in the laboratory is not required.

The President's National Space Policy reaffirms the goal of promoting international activities in space where these activities are in the national interest. This reinforces a NASA objective mandated by Congress with the passage of the Space Act in 1958. The numerous successful projects NASA has conducted with other nations attest to the wisdom of the directives.

In many instances, foreign aerospace capabilities are now fully mature and competitive with those of the United States. Thus other nations could make genuinely significant contributions to a United States space station, were we to embark upon such a program. These contributions, if determined to be appropriate, would have the effect of adding to the station's capabilities at no additional cost to the U.S. Treasury.

In the past year, we have seen significant self-generated foreign interest in our space station definition planning activities. Several countries, while realizing that there was no approved U.S. program and no commitments, have spent their own funds on parallel station studies, and have shared their results with us.

Any cooperative venture on a future space station would need to guard against the unwarranted transfer of U.S. technology to our competitors abroad. Technology, particularly aerospace technology is an area of strength for the United States in what is now an intensely competitive world. Markets are global and we must not make it easier for those whose products compete with our own to gain a competitive advantage. With care and common sense, we can continue the benefits provided by international cooperation in space yet accommodate legitimate concerns with technology transfer.

Mr. Chairman, as we have conducted our space station planning activities, we have sought to involve those communities who might take advantage of the capabilities a space station would offer. This involvement has included the Department of Defense. The Department contributed funds to the mission studies and has provided an officer from Space Command to the Space Station Task Force. This cooperation has been, I believe, mutually beneficial. In addition, the Department has conducted some space station studies of its own. I believe that it is most important for NASA and the Air Force and Department of Defense to keep each other well informed of our space station planning activities.

In the future NASA hopes to increase the benefits our many activities in space provide. These activities, in science and applications, in launch vehicles, in technology and in the area of commercial endeavors offer tremendous potential for the years ahead. I foresee a future in which we will have on orbit large astrophysical observatories, where we have over time built up a system of earth-looking imaging systems, where a stable planetary program results in periodic missions, and where commercial endeavors in space are significant in both number and benefit. Such a future could reflect an infrastructure with the following characteristics:

- The ability to assemble large structures;
- Improved transportation from low-Earth orbit to geosynchronous orbit;
- On-orbit flexibility in maintenance and repair;
- Suitable accommodations for living and working in space;
- Removal of the mystique associated with manned space flight.

These are all characteristics or capabilities associated with a potential future space station. In the long run, a space station would help establish this infrastructure and preserve future options for a truly major new national endeavor in space. It could be a stepping stone to future space exploration.

That concludes my prepared statement this morning. In the time remaining I will try to answer any questions that you may have.

STATEMENT OF JOHN D. HODGE, DIRECTOR, SPACE STATION TASK FORCE, NASA

Mr. Chairman and Members of the Subcommittee: It is a pleasure to appear before you today to discuss the activities of NASA's Space Station Task Force. This testimony will briefly review Task Force activities over the past 18 months and planned activities for fiscal year 1984 as well as plans for potential definition and development activities. Finally, alternative and evolutionary approaches to space station development will be discussed.

As noted in Administrator Beggs' testimony, the issue of whether the United States should commit to the development of a space station is currently under review within the Administration and no space station development program currently exists. The activities of the Space Station Task Force are designed to assemble the necessary information for both the Administration and Congress to make an informed decision.

BACKGROUND

The concept of living and working in space is far from new. Authors wrote on the subject in the last century and space station configurations have been set forth since the 1920's. During NASA's 25 year history, a wide variety of concepts and configurations have been studied in some depth. These concepts range from elaborate configurations with artificial gravity and crews numbering several dozen to simple derivations of developed space hardware such as the Apollo command and service module. And, of course, slightly more than ten years ago, the United States orbited a precursor space station—Skylab, which was occupied by three, three-man crews for periods of 24, 56, and 84 days.

What then is new or changed today to warrant the planning activity that NASA has undertaken? First is the growing operational maturity of the Space Transportation System. In the late 1960's when the Space Shuttle was in the conceptual stage, it may be recalled that a body of professional and technical opinion proposed that the next logical step following the completion of the Apollo program should be the development of a permanent space station. Indeed, significant parallel space station definition efforts were conducted by the Johnson Space Center and the Marshall Space Flight Center in 1970. The decision, however, announced by President Nixon in early 1972, was to first develop a transportation system—the Space Shuttle—and as you are well aware this effort has been the centerpiece of this Country's space capability development for the past decade. But with the Shuttle having transitioned into initial operational status it is now time to plan for the next logical step in the exploration and exploitation of space. As Administrator Beggs testified before the Subcommittee in his confirmation hearings over two years ago and has reiterated, he believes that a permanent space station is that next logical step.

Second, in addition to the development of the Shuttle there have been significant space station studies since the Skylab missions ten years ago. Indeed, the space station concept of today encompasses many new and broader space-based capabilities. In addition to the science and applications laboratory functions performed onboard Skylab, today's concept includes the servicing of free-flying satellites and platforms, the assembly of large structures in space, space-basing of upper stage vehicles and propellants, and promising commercial manufacturing and materials processing missions.

In May of last year, Mr. Beggs established the Space Station Task Force to give focus and direction to NASA's space station planning in order that the necessary information would be available for an informed decision by both the Administration and the Congress.

PLANNING GUIDELINES

Many significant aspects of a potential space station program make it unique when compared to major program initiatives of the past. These considerations taken together have dictated a set of planning guidelines or boundary conditions which have guided the activities of the Task Force. The major guidelines are set forth below:

User community involvement—To successfully accomplish the program's goals which are consistent with those of the National Space Policy, a concerted effort has been made to involve all potential users from the beginning of planning activities.

Potential users include the science and application communities, national security interests, the aerospace industry, a broad spectrum of commercial interests, technology development users, and international users. If a space station program is undertaken, the totality of these requirements will represent a continuously changing, most likely growing, spectrum of requirements which will need to be continuously refined, updated, and accommodated in a phased manner to achieve the best balance between resources, capabilities, and technology readiness.

Extensive definition prior to program installation—One of the major conclusions of NASA's 1981 Project Management Study (Hearth Report) was identification of the need for thorough project definition prior to implementation of the hardware phase. Space station program planning guidelines envision an extensive, three-year definition effort, including an intensive in-house concept development or system engineering activity followed by an extended contractual definition effort. The initial, in-house definition activities would be intended to sharpen Agency "buying" capabilities and lay the foundation for on-going systems engineering and integration activities during the contracted definition effort.

Agencywide participation—The breadth of the program includes potential for substantive involvement by all NASA installations. Because a potential future program would be more than an extension of previous manned space flight programs, all NASA installations have been involved in our planning activities through representation on the Task Force and Task Force Working Groups. Program success is critically dependent upon involvement of the science and applications communities as well as technologies generated by the research centers.

Evolution: An underlying theme—Prior to development of the Space Transportation System (STS), NASA's programs have used systems with limited evolutionary capability. The inherent nature of "permanent presence", however, calls for a program measured in decades, one which must be designed to accommodate possible evolutionary growth through incremental addition, modification, and replication. It must be capable of evolving not only in size but in technology, to assure that its utility is not short-lived. Present planning must also consider operations and growth beyond low-Earth orbit (LEO). An operational station, properly planned, could lay the foundation for the succeeding major step, be it manned operations at geosynchronous orbit, a lunar base, manned Mars mission or sample return, or other missions beyond Earth orbit; including such exciting prospects as the mining of precious resources from the asteroids.

Maintainable and restorable—For truly effective operational capability, space station elements would need to be amenable to on-orbit crew maintenance and, in the event of failure, capable of being restored to operational effectiveness. Cost effective operations for a program of this duration dictate that previous single mission, multiple redundancy approaches be replaced by routine maintenance and subsystems that are inherently "restorable" on orbit.

Operational autonomy—To the greatest extent possible, the initial configuration of a potential future station should be operated independent of ground control. Ideally, the station would be operated autonomously on orbit except for logistics resupply. Operational control would be retained by NASA but non-government personnel could perform science observations and manufacturing tasks on-board.

International participation—We have seen a tremendous interest in our space station planning activities by many of our long-standing cooperative partners. ESA, Canada, Japan, France, Germany and Italy conducted parallel mission analysis studies at their own initiative and expense. In addition, they are examining potential contributions to a future program. These early discussions are important for both NASA and its potential partners. Since the space station is viewed as a working orbital facility, NASA is gaining information on potential worldwide space station utilization patterns. Given the scope and complexity of a space station, this early involvement has given both NASA and the international community time to carefully evaluate cooperative possibilities, should the decision be made to proceed.

Department of Defense (DOD) cooperation—As Mr. Beggs has testified, we have kept DOD fully informed of our activities and they participated with limited funding in the mission requirements studies. However, the DOD has not, as yet, identified any requirements for a manned space station.

Cost approach—Several unique aspects of a potential space station environment offer the promise of lower cost through new approaches. The station, which is envisioned to be deployed and serviced by the Space Shuttle, will have few weight and configuration constraints as compared to past programs. Many of the space station elements would utilize subsystems which could be developed in common and utilized in a distributed manner. Modularity between elements and the use of common hardware also offer promise for lower overall costs.

The continuous and evolutionary nature of a potential space station program could also allow the development, testing and upgrading of new systems and components in an operational setting, obviating the need for some of the currently necessary ground qualification testing.

Proper mix of man and machines—Experience in the Skylab program and many studies have demonstrated the utility of human capabilities in a space station system. However, many potential missions could be best performed in an automated mode with only periodic human intervention or remote "telepresence". A major objective of the planning activities is to define the proper mix of man and machine in a potential space station setting to properly distribute the necessary tasks so that machines will enhance human capabilities and vice versa.

MISSION REQUIREMENTS

The first year of Task Force activities was directed almost exclusively to the identification of potential space station mission requirements as opposed to how a future space station might be configured or what elements would comprise such a station. The primary focus of the initial mission requirements phase were eight studies contracted to major aerospace corporations. The study contractors were given little specific direction but were encouraged to imaginatively explore all aspects of potential space station utilization. These contracts were initiated in August of 1982 and final reports were received this past April.

The conclusions of these studies were generally consistent across the eight contractors. To briefly summarize, the studies recommended an initial station consisting of a manned base with an unmanned platform at an orbital inclination of 28.5°, an Orbital Maneuvering Vehicle (OMV) operating in conjunction with the station, and a second unmanned platform serviced by the Shuttle, but derived from the space station design, operating at a near-polar or 90° inclination. It was generally concluded that these space station elements would have sufficient capability to perform significant missions in the areas of science and applications, the servicing of satellites, technology development experiments and promising commercial applications such as materials processing and communications. The studies addressed space station missions which would be time-phased consistent with realistic programmatic and budgetary expectations as well as evolutionary growth of the station itself. A very significant general finding in the area of early evolution of station capabilities was the potential of a space-based Orbital Transfer Vehicle (OTV) for access to geosynchronous Earth orbit and beyond.

During the period of NASA's mission requirement studies, significant international interest developed and, as mentioned above, a number of foreign countries conducted parallel studies on potential space station missions. While NASA and these foreign entities recognize that potential exists for international cooperation, all parties clearly understand that no space station program has been approved and that NASA cannot and has not made any commitments at this time. Periodic meetings have been held, however, to exchange study results. This activity has been very useful to an understanding of the totality of potential space station uses.

Following the mission requirements final reports this past April, which identified potential uses for a space station, a Space Station Mission Synthesis Workshop was held from May 6-13 at NASA's Langley Research Center. Participants included NASA, National Oceanic and Atmospheric Administration (NOAA), U.S. Air Force, and industry representatives. In addition to the findings of the mission requirements studies, the examination included the results of in-house studies and recommendations and reports from advisory committees. The results of this workshop were a time-phased set of possible space station missions for the period 1991 to 2000 in the fields of science and applications, technology development, and commercial applications. A preliminary total of 107 types of missions were defined for this time-frame and computerized data base was established.

In order to derive an initial space station "architecture", a set of missions was then selected for the first three years of station operations. The term "architecture" is used here to define the elements necessary to provide the functional capabilities for a potential station. A specific configuration or interconnection of elements is not implied or necessary to define the architecture. The baseline requirements identified for the initial missions set included a manned element at 28.5° inclination plus two platforms (in both low and polar inclinations), as recommended by the study contractors. The most stringent resource requirement appears to be the power required by the users or space station customers.

Before proceeding to a description of space station concept development, it should be emphasized that the identification of mission requirement, that is, user or cus-

tomer needs, would be a continuous and evolving process. Many of the potential missions identified were missions already planned for the 1900-2000 time period. These missions were not conceived in the context of a space station capability but were assessed to determine if they could be carried out onboard or through the capabilities of a station. As time progresses and space station capabilities are more fully understood by the potential user community, two things could happen. First, those missions which are presently planned to be carried out through currently existing capabilities could be modified to match the capabilities that a permanent space station would afford. Second, new missions, not now thought of or possible with existing capabilities, could emerge. In view of this, the Task Force has been structured to continually assess customer needs and fit these requirements into the definition process. Should a space station ultimately be developed, it will be essential that the facility be, to the greatest possible extent, fully responsive to customer needs.

CONCEPT DEVELOPMENT

Last April a Concept Development Group (CDG) was formed as an arm of the Task Force to orchestrate ongoing trade studies and integrate the results of the mission requirement studies into a set of functional capabilities, or "architecture". Four iterations of space station architecture are planned. The first was completed in May in conjunction with the Senior Interagency Group study requested by the President. A second iteration was completed in July for use in the preparation of NASA's FY 1985 budget submission. A third will be completed in December, and the fourth and final iteration is planned for completion just prior to the planned initiation of the contracted definition phase. Through this iterative process, a thorough and extensive definition will be based on the most current mission sets, functional capabilities, and budget plans.

The space station concept currently under consideration includes the following elements:

- Living Quarters Module.
- Berthing and Assembly Module.
- Logistics Module.
- Resources Module.
- Laboratory Module.
- Platform at 90°.
- Platform at 28.5°.
- Orbital Maneuvering Vehicle.
- Servicing System.

It should be noted that an approved configuration does not exist and some of these elements as well as estimated costs could change.

The CDG, in concert with the selected field centers and contractors currently has underway a series of study tasks to define options which are essential to architecture selection. Key areas such as automation, maintainability, modularity, and satellite servicing are included. A series of workshops is being held in Washington, D.C., to review the status and findings of the various study task participants.

TECHNOLOGY AND ADVANCED DEVELOPMENT

Prior to the creation of the Space Station Task Force, NASA formed a Space Station Technology Steering Committee (SSTSC) to assess technologies relevant to a space station in the 1990 timeframe. The SSTSC concluded that use of state-of-the-art technologies would result in a station that would not have affordable growth potential and would not be cost effective for long-term life through on-orbit maintenance. The SSTSC identified those advanced technologies necessary to meet space station goals. A major workshop was held earlier this year to review technologies in the NASA program and industry R&D programs relevant to a space station development.

Additionally, a space station advanced development program is being defined to provide needed advanced technology options to support the initial and evolutionary space station. To support this initial capability, test beds are planned in key technology areas such as power, life support, and thermal systems. To coordinate this advanced development program within NASA, the Space Station Task Force is working our agreements with the NASA program offices.

FISCAL YEAR 1984 ACTIVITIES

NASA's space station activities for fiscal year 1984 total \$14 million, consistent with the fiscal year 1984 HUD-Independent Agencies Appropriations Act. This funding is distributed in Space Flight, Advanced Programs: \$6 million; Space Research and Technology: \$6 million; and Space Science and Applications, Spacelab Payload Development and Mission Management, \$2 million. The plan for this fiscal year includes funding for utilization requirements, supporting studies, focused technology, advanced development, and program support. These activities will support in-house definition efforts.

Utilization requirements efforts will continue to develop space station functional requirements based on an integrated set of potential missions. Funding will also be used to develop operating plans to ensure that the total system is responsive to customer needs. In order to continue to explore potential commercial utilization of a space station, two small studies were initiated earlier this year. These study contractors are pursuing commercial interests identified during the mission analysis studies as well as examining institutional mechanisms to enhance the interaction between the private sector and the government to achieve full and early commercial access to a station. Also, a commercial working group has been established within the Task Force to provide a focus for commercial space station opportunities.

Supporting studies will continue to define space station architecture as well as preliminary system and subsystem requirements, develop and assess operational concepts, and identify technology and advanced development requirements. Examples of such studies include human productivity, structures and mechanism, auxiliary propulsion, and satellite and OTV servicing. These studies will complement ongoing in-house trade studies at a number of field installations.

NASA's space technology efforts in support of potential space station applications fall into two categories. The first, referred to as "generic technology" and totalling approximately \$30 million in NASA's fiscal year 1984 Space Technology budget, is that technology work that would be applicable to a space station development but could also support other space activities. Examples of such technology areas include auxiliary propulsion and data management. Focused technology, on the other hand, is directed toward specific space station applications and is intended to provide specific enabling or enhancing technology design options. This funding is intended to carry specific technologies into brass-board or advanced development stages. Fiscal year 1984 focused technology funding is planned for the areas of system operations, data management, human capabilities, and communications.

The primary objective of the advanced development program is to create a transfer function between technology and system development. The program will focus on the test beds keyed to major subsystem disciplines. The test beds will be located at various field installations and employed to evaluate technology alternatives, quantify performance, and estimate development risk from both a cost and schedule standpoint. Fiscal year 1984 funding is planned for advanced development activities in the areas of environmental control and life support, electrical power, thermal management, and onboard propulsion. A number of other discipline areas such as data management and space operation mechanisms are also included in the program. Programs support activities funded in fiscal year 1984 include information systems activities as well as necessary institutional support.

In addition to the items mentioned above, a number of potential Shuttle flight experiments have been identified to validate the performance of certain components and subsystems. Such experiments could demonstrate tools, sensors, and techniques and procedures required for space station control repair and servicing operations. In fiscal year 1984 in-house efforts will be directed at identifying candidate demonstrations and developing plans for experiment execution.

ALTERNATIVE APPROACHES

As mentioned earlier, NASA has studied space station concepts for many years. Those studies have examined a wide variety of approaches, including both manned and unmanned configurations. The Space Operations Center (SOC) concept, for example, developed by the Johnson Space Center in the mid-1970's examined an approach which utilized Shuttle capabilities to assemble space station components in orbit. The SOC concept included capabilities to assemble large structures and service vehicles in space-based "hangers". At about the same time the Marshall Space Flight Center conducted studies of unmanned space platforms for science and applications missions. These studies included an evolutionary approach through which an unmanned platform could be evolved into a habitable facility.

Over the past year, a series of broad options have been reviewed based on selected scenarios for conducting future space operations. These scenarios range from continuing with the current Space Transportation System operating with free-flying (unmanned) satellites to a system including a fully evolved Space Station operating with the STS.

One potential issue arising from alternative approaches to space station capability is the interim or perhaps even long-term use of a Space Shuttle orbiter or orbiters modified to extend their stay time in orbit. While this had been the subject of reviews in past years, we are currently reviewing the capabilities this would provide as well as the associated costs. Total stay time on orbit and habitability provisions are key issues as well as possible impact on the mission manifest and fleet size.

Another significant issue in the approach to any future space station capability is the role of automation and robotics and the extent to which machines can replace and/or enhance the role of humans in space. The Task Force is currently conducting an examination of the future role of humans in space and the potential of robotics and artificial intelligence in the development of space-based capabilities. A report on the results of this review will include a projection of the state-of-the-art in robotics and artificial intelligence by the year 2000, and include an assessment of the partitioning of functional requirements between man, robotics and automated elements.

SUMMARY

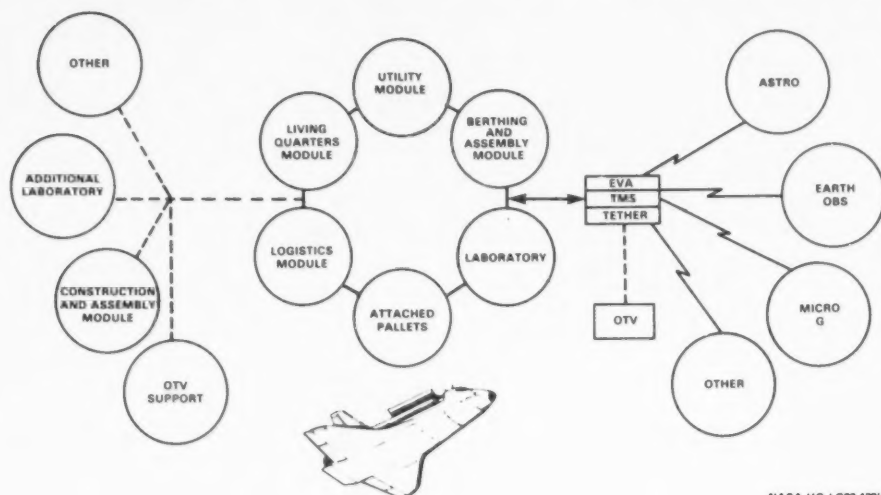
NASA has studied a variety of space station concepts over many years. For the past eighteen months, we have conducted an in-depth planning activity identifying potential mission requirements and functional capabilities. Potential space station architectures are being developed and iterated in response to those postulated requirements and capabilities. These FY 1984 activities are designed to provide both the Administration and the Congress sufficient information to make an informed decision with regard to the potential future development of a space station as part of the Nation's civilian space capabilities.

A SPACE STATION ARCHITECTURE: CLUSTER CONCEPT

GROWTH ELEMENTS

BASE

UNMANNED PLATFORM



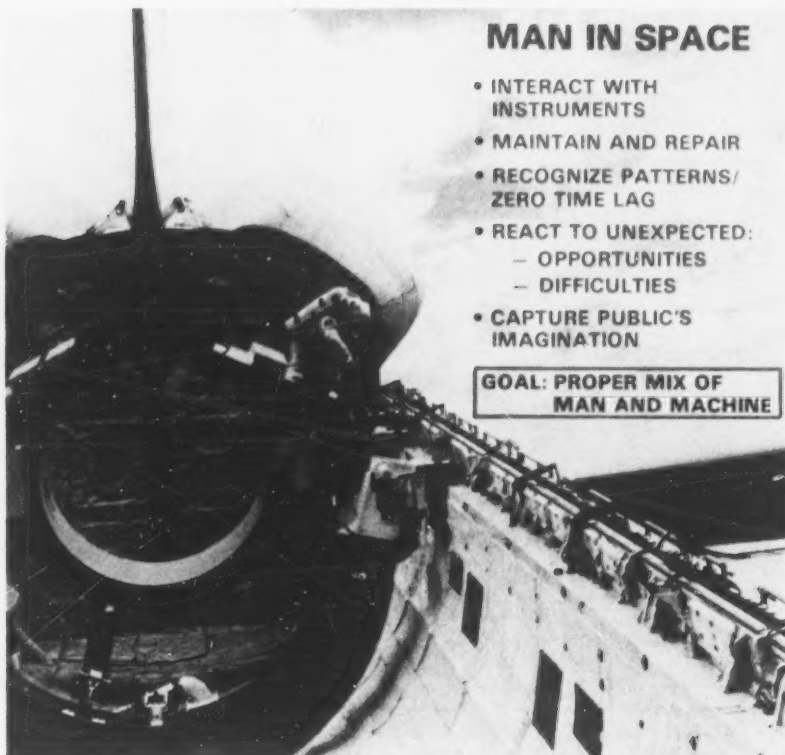
NASA HQ LGB3-130(1)
Rev. 10-3-83

FUNCTIONS OF A SPACE STATION

- On-orbit laboratory
 - Science and applications
 - Technology and advanced development
- Permanent observatory(s)
- Transportation node
- Servicing facility
 - Free flyers
 - Platforms
- Communications and data processing node
- Manufacturing facility
- Assembly facility
- Storage depot

A space station is a multi-purpose facility

NASA HQ MF83 2423 (1)
Rev. 7-25-83



MAN IN SPACE

- INTERACT WITH INSTRUMENTS
- MAINTAIN AND REPAIR
- RECOGNIZE PATTERNS/
ZERO TIME LAG
- REACT TO UNEXPECTED:
 - OPPORTUNITIES
 - DIFFICULTIES
- CAPTURE PUBLIC'S IMAGINATION

**GOAL: PROPER MIX OF
MAN AND MACHINE**

NASA HQ MFB3 2205v31
REV. 8-2-83

SPACE STATION PLANNING GUIDELINES

MANAGEMENT RELATED

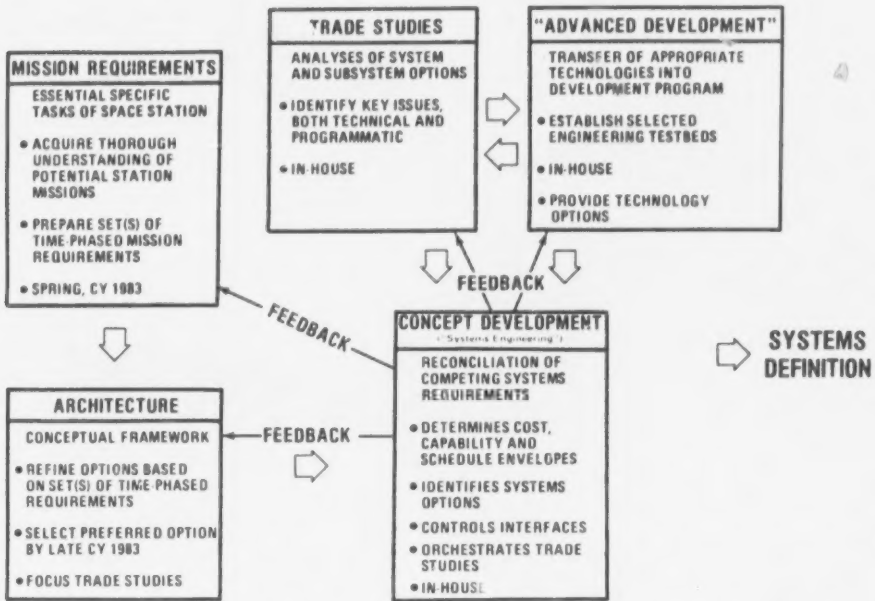
- Three year extensive definition (5-10% of program cost)
- NASA-wide participation
- Development funding in FY 1987
- IOC in 1991
- Cost of initial capability: 8.0B
- Extensive user community involvement
 - Science and applications
 - Industry
 - DoD
 - Commercial
- Possible international participation

ENGINEERING RELATED

- Continuously habitable
- Shuttle dependent
- Manned and unmanned elements
- Evolutionary
- Maintainable/restorable
- Operationally autonomous
- User friendly
- Technology transparent

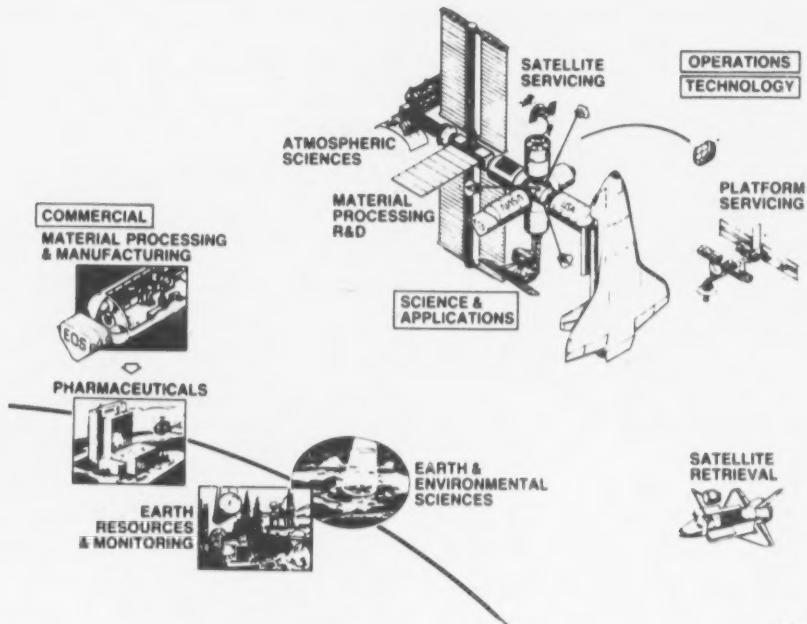
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REV 11-1-83

SPACE STATION DEFINITION ACTIVITY



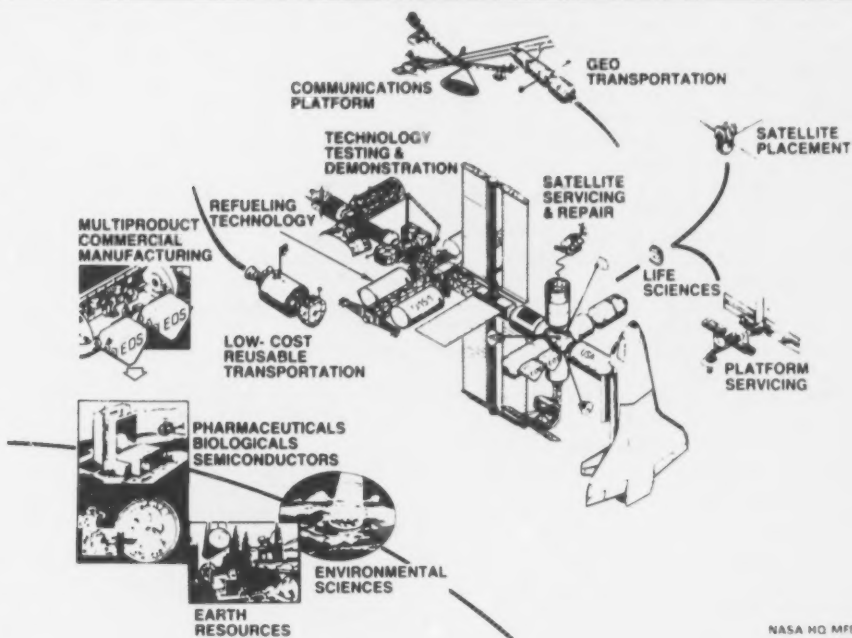
NASA HQ LG83-894 (1)
 Rev. 5-24-83

SPACE STATION INITIAL



NASA HQ MF 83 2271
 6-3-83

SPACE STATION FUTURE



NASA HQ MFB3 2276-11
6-3-83

SPACE STATION: EARLY CUT AT CAPABILITIES

	INITIAL	FUTURE
BASE AT 28.5°		
Crew	6-8	12-18
Power	75KW	160KW
Attached payloads	Some	More
Servicing capability	Initial (close by)	Mature
Smart front-end TMS	Available	Available
Data system	300 MBPS	300 MBPS
Utility module	One	More
Laboratory module	One	More
Logistics module	Two	More
Living quarters module	One	More
Multi-berthing adapter	One	?
PLATFORMS		
28.5°/15KW	One	Several
Polar/15KW	One	One
SPACE-BASED OTV		
	No	Yes
MANNED POLAR STATION		
	No	?

NASA HQ MFB3-2422-111
Rev. 10-14-83

BEST COPY AVAILABLE

QUESTIONS OF THE COMMITTEE AND THE ANSWERS THERETO

Question. The idea of achieving a permanent human presence in space by "telepresence" has been discussed in the context of keeping the human on the ground and only placing his sensors and effectors in orbit. Your statement indicates that many potential missions could be best performed by remote telepresence.

a. What are some of these potential missions?

b. What are the current and forecast limits to achieving this telepresence?

Answer. a. A space station has been proposed as a multi-function, multi-purpose asset. There are some functions that must be implemented with man's presence on-board the space station and cannot be implemented with man located remotely. Some of these functions are:

Trouble-shooting and analysis of equipment operational anomalies not covered by built-in diagnostic systems.

Physical removal and replacement of failed or otherwise inoperable systems components where this is desirable.

Operation of teleoperated or telepresence equipment in unstructured situations. Handling and care of experimental animals and plants in long space medicine and biology experiments.

Set-up and observation of complex space-based experiments where robotic applications would be too complex for ready accomplishment.

Reaction to anomalies behavior of experiments or observation of new phenomena not previously encountered.

b. The limits to achieving telepresence involve:

The time constant of the functions to be performed.

The state-of-the-art of computers and expert systems.

The information band available to transmit sensor and command information from orbit to the ground. Each function must be analyzed in consonance to the projected state of the art to determine the viability of performing the function with man located remotely. The Space Station Task Force is performing an analysis to determine the limits to achieve this telepresence with the assistance of Professor Theodore Williams of Purdue University, a recognized expert in industrial robotics.

Question. According to your testimony, the Space Shuttle orbiter is now capable of a maximum in-orbit time of about 9 days. Also, some attention has been given to the concept of an "extended duration orbiter", in which the Space Shuttle orbiter may be modified to achieve an in-orbit time of 20 to 30 days, at less cost than a space station development.

a. What would be the total cost to modify a Shuttle orbiter to achieve a 21 day capability and to achieve a 30 day capability?

b. Why hasn't an extended duration orbiter been incorporated into NASA's space station plans as an interim testing environment for space science and space applications experiments prior to their use on a space station?

Answer. a. The costs to modify an orbiter for extended durations beyond the current approximate maximum on-orbit stay time of 9 days have been only very roughly estimated at this time. These estimates range from \$100 million to \$150 million (in fiscal year 1984 dollars) for a two to three week capability and up to \$1 billion (in fiscal year 1984 dollars) for a four to nine week capability.

An increase to two to three weeks can be achieved by adding cryogen tanks along with supporting structure, plumbing and avionics, to place a cryo wafer into the orbiter bay. This option, which will displace about seven linear feet of payload space in the orbiter bay, could be a fairly straightforward augmentation to the existing cryo system of five tank sets (which service the orbiter's fuel cells) by adding another five tank sets. In addition, a minimum mod approach would provide for additional water, LiOH canisters and some stowage and habitability accommodations.

An increase to more than about three weeks on-orbit, however, appears as though it might require new development of a 48 kw Solar Array Energy Module and extensive modification of orbiter systems. Among the modifications are: additional LiOH racks and tanks, or, development of a CO₂ regeneration system; additional potable water; additional waste collection and removal; additional habitability requirements (possibly requiring modifications to the Spacelab for habitability); additional stowage; orbiter mid-deck modification; redesign of the Orbiter Vernier Thrusters to prevent depletion of propellants during frequent sun orientation maneuvers; new capability software loads for ascent/descent, on-orbit maneuvers; etc. A penalty of this option is the large "scar-weight" required for an orbiter so modified, which will reduce total payload capacity for any mission regardless of duration.

b. Current space station planning does include provisions for flight experiments onboard the Shuttle to validate the performance of space station components and

subsystems in the space environment. These experiments would demonstrate techniques and procedures as well as sensors and tools which would be required for space science and applications experiments on a space station. No requirement, however, has been identified for an extended duration orbiter to perform these Shuttle flight experiments.

Question. What information is currently available to indicate that the benefits of alternative methods of accomplishing NASA's goals for a space station?

Answer. There are some functions that could be enhanced by a space station. Example of such functions are the use of a space station as a transportation mode to higher energy orbits and the use of a space station for the construction of large structures in space. Other functions could conceivably be performed by alternative methods. Analyses of some of these concepts indicated that these alternative methods could be more costly than the space station approach.

Question. The private sector is becoming increasingly interested in space commercialization. To what degree would commercial space activities be hindered by the absence of space station?

Answer. Many experiments, for example, materials processing in space, probably cannot be done unless long duration at low-gravity can be provided. Efforts to produce pharmaceutical materials in the quantity to make a commercial venture viable may require three to six months of long duration low-gravity time. The same is also true of many materials that are candidates for electronics applications. Space station servicing capabilities, including provisions for manned supervision and intervention, are important to the accomplishment of successful space manufacturing.

Question. NASA's activities have generated for the U.S. economy many technological spinoffs, such as in the fields of medicine and industrial productivity.

In what ways and to what degree are space station technological spinoffs expected to affect the U.S. economy?

Answer. With high technology efforts such as the Space Shuttle or a space station, it is true that new and advanced technologies developed will have an impact on nonaerospace segments of the U.S. economy. However, these are difficult to predict or directly quantify. Potential exists for technological spinoffs from many areas including new communications capabilities, remote sensing capabilities, and many areas including the influence of space-based research, the current joint endeavor in electrophoresis is expected to result in a new set of pharmaceuticals that have great market potential.

Question. Industrial uses on a space station may account for significant power and data transmission requirements.

What assurances are there that industry will contribute proportionately to the program, and when?

Answer. There are none. NASA is now in the process of defining the power and data transmission requirements for the totality of payloads that we can now anticipate would utilize space station capabilities. The capabilities of industry to participate in assisting NASA to meet these requirements are essential to successful execution of the program. If a commitment is made to proceed with a space station, NASA will call upon industry to use its best resources to meet our defined requirements.

Question. The Department of Defense has said that no military requirements have been identified for military space station operations.

If NASA were to begin space station definition studies in fiscal year 1985 and the development of a space station in 1987, under what circumstances would NASA consider DOD inputs regarding the requirements for the utilization of a space station?

Answer. DOD inputs to NASA with regard to requirements, should they evolve, would be received by the Space Station Mission Requirements Working Group where they would be integrated with other mission requirements associated with science, technology and commercialization missions. A DOD representative is a member of the Space Station Task Force and DOD is kept fully informed of the status of NASA's planning activities.

Question. If a space station were deployed by 1992, what would be the involvement of the Defense Department, in terms of operation, manpower, and communications?

Answer. At this time, DOD has identified no requirements for a space station. While NASA has kept DOD fully informed of our activities, the answer to the question would best be provided by DOD.

Question. How vulnerable would a space station be to enemy attack and what defensive mode would be required to protect a space station?

Answer. A peacetime attack on a U.S. space station would be violation of the United Nations' charter as well as the Outer Space Treaty of 1967 (Treaty on Prin-

ciples Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and other Celestial Bodies).

A second aspect is that the only country currently with an ASAT (anti-satellite) capability is the Soviet Union, which also has a space station. If the Soviet Union were to attack a U.S. space station, the USSR obviously would be putting its own space station at risk; something that presumably they would not be anxious to do.

Finally, development of a U.S. space station is still in the concept definition phase and has not yet matured to the point where hardware design or engineering specifications are being considered. As the program proceeds, however, engineering data will become available and vulnerabilities will become more apparent. At that time, appropriate defensive mechanisms or tactics/techniques will be addressed based upon the assessed threat of a potential enemy attack.

Question. According to your testimony, NASA's estimated cost for a space station with an initial operating capability in 1991 is approximately \$8.0 billion. Also, you indicate that NASA would like to begin, initially, with an extensive three-year definition error.

a. What would be NASA's budgetary requirement for these definition studies in fiscal year 1985, fiscal year 1986, and fiscal year 1987?

b. What effect would a fiscal year 1985 new start of this magnitude have on other existing programs, such as those for space science and space application, and on future NASA programs?

c. What are the major drivers or considerations behind the space station costs?

d. What is the estimated annual cost to operate the proposed initial space station complex?

Answer. a. Estimated space station definition funding including such effort as utilization requirements, supporting studies, focused technology/advance development, flight experiments and systems definition/integration for the next three years is:

[Constant 1984 dollars in millions]

Fiscal year:

1985.....	\$190-235
1986.....	225-270
1987.....	125-170

b. A commitment to the development of a space station would necessitate a review of future science and applications programs so that the maximum potential offered by a space station could be realized in the planning and implementation of those new programs. The funding of the science and applications programs within NASA has been a fairly consistent percentage of the total NASA budget over the history of the Agency. It would be our intent to maintain a level of funding that would enable the science and applications communities to accomplish a meaningful, productive program which would ensure a continuing leadership role for the United States in these fields.

c. The major consideration behind the definition costs are advanced technology development and phase B contractor definition activities. By supporting an extensive effort in both areas over the next three years, we hope to be able to reduce the operational and utilization costs of a potential future space station. Also, by employing new operational concepts such as common subsystems which are maintainable for long-term use and extensive onboard autonomy, we hope to be able to significantly reduce the cost of operations.

d. Space station operational costs are being considered as a part of the overall review of the potential program beyond the planned initial launch of the station. Reliable estimates are not yet available.

Question. What do you estimate the annual NASA budget requirements would be for fiscal years 1985 through 1991 to build the space station and to maintain the current size of the other NASA programs.

Answer. Preliminary projections indicate that a space station could be developed within a funding envelope representing a modest real growth rate (about 2 percent) in the total Agency budget while maintaining the current size of the other NASA programs, if current projections of ongoing projects and potential new starts are accurate.

Question. One of the lessons learned on the Space Shuttle program was that underfunding in the early years resulted in program delays and cost growth.

What steps or precautions have been taken to preclude underfunding in the early years that could result in similar delays and cost growth on the space station program?

Answer. The underfunding of the Space Shuttle in its early years was due to optimistic cost, schedule, and inflation estimates. With the extended definition period

planned for a space station, we should be able to provide more reliable cost estimates.

Question. NASA's planned space station with a 1991 initial operating capability is to be the first step in the modular design of a much larger space station.

What do you estimate the total program cost will be for the total space station concept?

Answer. We do not have an estimate for the eventual space station concept because the system will be modular and the extent of the eventual concept will be subject to future decisions.

Senator GORTON. At this point we will hear from two representatives of the National Academy of Sciences, Mr. Harter and Dr. Donahue. Mr. Harter, you may proceed.

STATEMENTS OF GEORGE A. HARTER, CHAIRMAN, SPACE APPLICATIONS BOARD; AND DR. THOMAS M. DONAHUE, CHAIRMAN, SPACE SCIENCE BOARD, NATIONAL ACADEMY OF SCIENCES

Mr. HARTER. Mr. Chairman and members of the committee, on behalf of the Space Applications Board of the National Research Council, I would like to thank you for the invitation to participate in this hearing this morning. My purpose is to present, as you requested, the current thinking of the board on the potential uses of a civil space station.

My name is George Harter. I have been a member of the Space Applications Board since 1981, and have been Chairman since December of last year. I am presently employed by TRW, Inc., in Cleveland, Ohio, as vice president for planning and investment. Since joining TRW in 1957, I have held a number of technical and managerial positions in the spacecraft and electronics field; a brief biography is attached to the written copy of my statement.

The Space Applications Board was formed by the National Academy of Engineering in 1973, and is now a part of the National Research Council, the operating organization of the National Academies of Sciences and Engineering.

The Board's function are to help formulate the Nation's program for practical applications of space systems, to give independent advice to NASA and other agencies, and to assist in broadening the understanding of industry, universities, government, and the public of practical applications of space technology. The Board's charter and a list of its current members are attached to the written copy which was previously submitted.

Mr. Chairman, your letter of October 18 asked that we address three subjects: One, the uses of a space station; two, alternative approaches that would satisfy the requirements of such a space station; and three, the budgetary impact of the space station development.

My statement is concerned principally with only the first subject, the uses of a space station, because this subject has been studied intensively by our Board.

In the summer of 1982, at the request of NASA, the Board brought together about 30 recognized experts from various user communities to determine what practical uses a space station or a space platform might serve if it were to be developed by NASA, and what requirements should be placed on the design of a space station to make it most useful.

The study participants were divided into panels representing five user-oriented communities, and a sixth panel dealing with system design considerations.

An Earth resources panel dealt with applications of remote sensing for agriculture, hydrology, mineral exploration and similar areas.

An Earth environment panel dealt with the Earth's atmosphere and its impact on society, principally with respect to weather and climate.

An oceans observations panel considered subjects such as coastal preservation, fisheries development, mineral extraction, ocean pollution, sea ice monitoring, oil and gas exploration, and commercial shipping.

A satellite communications panel assessed the potential role of a space station in the evolution of commercial communication services.

Finally, a materials, science, and engineering panel focused on the utility of a space station environment for materials processing.

The report of the study is now in final review and should be published within the next few months. In the meantime, we have communicated the results of the study to the NASA Administrator by means of a letter from which I would like to quote.

Most observations intended to support Earth resources uses, Earth's environmental studies and ocean operations would require a near-polar Sun-synchronous orbit. This implies the use of a large, unmanned space platform in a low near-polar orbit. Such a platform could accommodate simultaneous observations by a cooperating array of instruments, the merging of data from the different instruments and the processing of data aboard the space platform prior to transmission to earth.

The utility of such a platform would be enhanced by the availability of a manned service station which could be used to service, repair, and if necessary, replace instruments on the platform, to recalibrate such instruments and to resupply expendables such as cryogenic coolants and propellants used for attitude control and stationkeeping.

A low earth orbit space station would provide little direct benefit for geostationary communication satellites before about the year 2000. However, it is possible that the manned station could serve as a fuel depot and a base of operations for launching larger communications platforms up to synchronous orbit. A low orbiting station could also be used for conducting some classes of communications experiments such as the deployment and evaluation testing of a very large antenna.

Our study panels consider the potential use of man both as an observer and as a facilitator. In general, they found no significant role for man in the acquisition of data. However, a manned space station could provide the capability for modification, repair and replacement of sensors and spacecraft in orbit. For example, the expensive and now dormant SEASAT oceanographic satellite could probably have been restored to operation if a means had been provided for its retrieval and repair. With respect to remote sensing, a manned presence would be more important during the research or exploratory phase of a new program. However, even in an operational phase, man's ability to identify transient phenomena, to monitor data quality, to adjust instruments rapidly, and to make in situ decisions on data handling might prove useful.

Our materials science and engineering panel envisioned a space station that would provide, in miniature form, a laboratory staffed with technically trained operators, similar in some respects to a materials laboratory here on Earth. For this application, the station would have to provide not only a disturbance-free, low-gravity environment, but also a large amount of electric power for materials processing, as discussed by Mr. Hodge.

In summary, our studies indicate that a manned space station, which included a remote sensing platform in near-polar orbit, could be useful and beneficial to the many space applications interest that I mentioned. Our Board has not studied to this point the cost-effectiveness of such a program relative to other alternatives. We feel that the effective utilization of the space station would require significant re-

sources beyond those required for development of the station alone. There would need to be an equal commitment to the timely development of instruments and payloads for use on the station and remote sensing platform.

Most of the foregoing is concerned with the uses of the space station or a space platform. Although our Board did not evaluate alternative approaches, it is clear that some of the uses of a space station will be satisfied in a preliminary fashion by the Space Shuttle as it becomes operational. Also, our Board is not in a position to evaluate the budgetary impact of a space station development except to note that, if undertaken, a space station would be a dominating item in NASA's future program.

Thank you.

Senator GORTON. Thank you, Mr. Harter.

Dr. Donahue.

Dr. DONAHUE. Thank you, Mr. Chairman, for your invitation to testify on the space station issue.

My name is Thomas M. Donahue. I am on the faculty of the University of Michigan and am the Chairman of the Space Science Board of the National Academy of Sciences.

It is the ongoing task of the Board to provide independent advice and guidance to the conduct and substance of the U.S. civil space science program and the major technical initiatives to implement such programs.

The Space Science Board recently produced two brief reports dealing with space science issues raised by NASA's proposal to establish a space station in a low inclination orbit by the end of this century. I have attached these reports to this statement, along with the transmittal letter, that I sent with them to Mr. Beggs, the Administrator of NASA.

So here I shall only very briefly summarize the content of these reports.

The first report addresses the question of whether the space station now proposed would significantly enhance the usefulness of space science missions it proposes to support above the level they would achieve, if the present space transportation system alone were available to launch and to support them.

In view of the fact that the missions set in question was designed around expendable launch vehicles—a shuttle and appropriate upper stages that are now being developed, it is hardly surprising that the answer turns out to be negative.

It is important to note that the Board addressed the question of just how much we need this particular space station, 40 percent of whose projected activity is stated to be support of a particular set of space science missions.

We explicitly remarked that we could envision other kinds of space stations designed to do other things such as providing an assembly base for construction of large structures or new kinds of spacecraft on orbit that might be very useful to space science missions of the future.

We suggested that we might be able to get enthusiastic about such a space station. However, it is only fair to say that I doubt that these kinds of activities alone could ever come close to justifying entirely the establishment of such a space station.

Indeed, we also pointed out in our second report our conviction that, in defining the proper use of a space station, one should have very clearly in mind all of the major functions it is supposed to perform. And I sense I am in a minority this morning on this issue.

But to be explicit, if sooner or later the space station is supposed to provide a base for expeditions to Mars or to the Moon, then that activity will so overwhelm the support of the platforms, free flyers, and space applications that one should pay attention from the beginning to the requirements of the more ambitious application of the space station.

I am not saying that the proposed space station will not serve well as a step toward that ultimate space station. I only point out that we have not seen the evidence that the issue is being addressed or that we understand the tradeoffs.

You might ask why we insist on evaluating the space station in terms of our science objectives and their present missions and do not consider revising them radically in view of the possibility that novel ways of configuring and servicing missions from a space station might be developed and provide us with exciting new capabilities.

The answer is partly that we are not being challenged to do that with the present proposal. It is also partly that our agenda is very full with the present set of missions. We are very excited about their potential to provide us with fundamental insights into how the universe began, insights into grand, unified theories of physics, into questions about the planets and the Sun developed, and life began, into how life on Earth impacts and is impacted by the atmosphere, the oceans, and the solid planet.

We consider this to be a very worthy agenda. We consider the technical means now becoming available adequate to allow us to get on with it, and especially after our experience with long, frustrating delays waiting for that system to be put in place, we are very resistant to risking another weight for another promised enhancement in supporting technology that, in our opinion, offers no apparent qualitative advantage over the shuttle system for science. That technology ought to grow in response to experience and evolving requirements and not be artificially introduced in such a way as to drive its uses.

It is significant that the pressure to build a space station is not coming from potential users such as space science and applications. Those who are pressing for a space station are making a laudable effort to involve those users in defining the characteristics of the space station so that it will be useful to them. This is in contrast with what happened when these communities were presented with the space shuttle and spacelab, two previous systems imposed on them. But, nevertheless, I have to emphasize the importance of the observation that technical means should develop in response to user needs and not the other way around.

It is often said that our response to the proposed space station is a consequence of our fears that science budgets will suffer from competition with Office of Space Flight budgets if the Nation should embark on a new and ambitious space station program. This is not an accurate characterization of our position.

A very simple examination of the record, as Mr. Beggs just mentioned, will reveal that the budget for space science has remained fairly close to a fixed fraction of the total NASA budget through all the 25-year history of the space program.

During the years of the Apollo era, this fraction served to support a vigorous and productive science program. During the years of the shuttle it has not. The reason is that during the sixties and early seventies the science budget was being used to build spacecraft, to launch them and to finance the science groups that used them.

During much of the last 10 years approved space science missions have been waiting on the ground to be launched because of delays in getting the shuttle operational and the unavailability of expendable launch vehicles. Thus, the budget has been used to support the infrastructure of engineers and technicians that must be maintained to take care of those missions until they are launched and not to prepare and fly new missions.

The rate of launching space science missions has dropped from five or six per year in the late sixties to about one per year now. Therefore, we have warned that if the Nation wishes to continue to do space science while a space station is being developed, the means to launch and support space science missions and to support the space science community will need to be preserved concurrently.

Nevertheless, the budget impact may occur. We are watching with great interest to see what is in the agency's fiscal year 1985 budget request. If the budget implications of large sums for the space station and for the consequences of management defects in developing the space telescope, our failure to propose new starts for the upper atmosphere research satellite, for the Mars geoscience climatology orbiter, the first planetary mission in the planetary observer series recommended by the Solar System Exploration Committee, or the various measures needed to bring emergency aid to failing university space science research groups, the conclusion will be obvious.

Early this year, after the magnitude of the problem with the space telescope development was revealed, the Board expressed to NASA and to the Congress our hope that the penalty for management failures would not be assessed against science. It is already clear, however, that the advanced X-ray astronomy facility and the solar optical telescope are being delayed.

Personally, I am apprehensive that delays also will be imposed on some or all of these other science missions that I have mentioned. If this turns out to be the case and at the same time funds are requested for a major new initiative for other elements of the space program, then a strong statement will have been made concerning priorities.

If this is indeed the direction which the Nation desires to take its space program, that is its prerogative. Whatever the decision, it is the duty of the Space Science Board to determine the scientific consequences.

Let me return for a moment to the statements the Board has published on the space station. We recognize that space science and applications are not the only ends of the space program, not by any means. We have not taken a position for or against the space station, although many read our position to be negative.

We hold that the decision to build a space station will be made for reasons other than its usefulness to space science and applica-

tions alone. In this regard, we are not very far from the position which was taken by Vic Reis this morning.

We also recognize that a healthy space agency is necessary for a healthy space science program, and that permission to embark on an ambitious new program such as the space station may be necessary or at least very salubrious for the health of NASA.

With these factors in mind we were reluctant to produce the judgment we did on the need of space science for the space station. However, the reason the Academies have established advisory bodies such as the Space Science Board and the Space Applications Board is to provide clear, independent advice on scientific and technical issues to those in Government who must come to decisions on those issues.

A crucial question is whether science can get along without the proposed space station and how well it can get along. These questions are very different from the question of whether we could use the space station if it were to be built or could use some kind of space station which may not even be the one proposed.

Earth sciences, for example, need observatories in high inclination, sometimes Sun-synchronous orbits. Such platforms and free flyers could benefit from services rendered by a manned space station in a high inclination orbit, but they could also be serviced from a space shuttle sortie in such a high inclination orbit.

Thus, to say that those observatories would be benefited merely because they are part of an overall plan labeled a space station plan that does not provide for the matching manned space station element would be an empty endorsement and is one that we chose not to make.

I hope that these remarks, coupled with the documents that I have submitted, will clarify some of the issues you must confront or provoke questions that I shall be pleased to answer.

[The material referred to follows]

NATIONAL RESEARCH COUNCIL,
COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND RESOURCES,
Washington, D.C., September 9, 1983.

Mr. JAMES BEGGS,

Administrator, National Aeronautics and Space Administration, Washington, D.C.

DEAR JIM: Last September the Space Science Board agreed to work with NASA in determining the technical capabilities a space station should have in order to address effectively the scientific objectives of the various space science disciplines. During the past year, the Board and its committees have had frequent interactions with the NASA Space Station Task Force, led by John Hodge, in fulfilling that commitment. We have been very favorably impressed by the careful consultation with the community of potential space station users that NASA has maintained during this exercise. In due time, we plan to transmit to you formally the results of the past year exercises by the Board and its committees.

Mr. Hodge has briefed the Board concerning the characteristics of the space station now being proposed by NASA. In the reports enclosed with this letter, the Board addresses two separate issues. The first issue is the degree to which the space station now being considered will be required in order to reach the objectives of the Space Science disciplines during the next twenty years. This evaluation, in the Board's opinion, must be made in the light of the adequacy of the presently available space transportation system to meet space science needs without augmentation by the proposed space station capabilities. Our finding is that present systems are adequate to these needs. Therefore, on the issue of meeting the needs of space science, our recommendation would be to use the space shuttle, together with requisite upper stages, maneuvering and propulsion systems for missions to be flown during this century. To meet longer range science objectives, a space station might prove to

be very useful in various ways if it were suitably designed. The Board would be happy to work with you to define such a space station if you proceed with plans for it.

As we pointed out in our letter of September 13, 1982, the Board agrees with you that the question of whether to go forward with a space station is not apt to be made on the grounds of its usefulness to space science and applications alone. Thus, the report entitled "Space Science Board Assessment of the Scientific Value of a Space Station" should not be regarded as establishing a Board position on the question of whether the nation should or should not now or in the future develop such a space station. On the other hand, the Board has considered some additional issues that lie within its competence. These have to do with conditions that should exist as any space station is being developed and after it becomes operational, if a healthy and vigorous space science program is to be maintained concurrently. A discussion of these issues is the content of our second report, "Space Science in a Space Station Era" which is also being forwarded to you with this letter.

Sincerely,

THOMAS M. DONAHUE,
Chairman.

SPACE SCIENCE BOARD ASSESSMENT OF THE SCIENTIFIC VALUE OF A SPACE STATION

During the past year, the Space Science Board has examined the question of what space systems are required to launch and support adequately the space science missions designed to attain the high priority science objectives identified by the Board and its committees. These missions are very numerous, challenging, and exciting. However, the rate at which they are launched would have to increase significantly above the current rate if all of the missions needed to fulfill this program are to be flown during the next two decades. The means of launching and tending them is now available or being developed in the form of expendable launch vehicles and the space shuttle, augmented as required by adequate high energy upper stages. One reason for the present slow pace is the delay in bringing the shuttle and its upper stages to full operational status. Another is that we have not yet learned how to use the shuttle efficiently and effectively as a manned orbiting laboratory. The Space Science Board urges that the present launch systems be fully and flexibly exploited and adequate resources be brought to bear so that the states objectives of space science can be reached in a timely fashion. The results of following this course should be a rich harvest of discoveries and insights in all disciplines of space science.

The Space Science Board has carefully examined the proposal by NASA for a manned space station in low Earth orbit designed to engage in a number of major activities. A significant portion of these activities involves support of space science missions. The Board has also examined the set of specific missions proposed for implementation from the space station system during the years 1991-2000. It has found that few of these missions would acquire significant scientific or technical enhancement by virtue of being implemented from this space station. In view of this and the adequacy of the present space transportation system for the purposes of space science, the Board sees no scientific need for this space station during the next twenty years.

In the longer term, the Space Science Board sees the possibility that a suitably designed space station could serve as a very useful facility in support of future space science activities. Such a space station could provide means for erecting and fabricating large and novel structures in space, and for servicing, fueling, and retrieval of payloads in orbit. If NASA wishes to develop plans for such an ambitious and technically demanding space station for the next century, the Space Science Board would be pleased to work with NASA in defining the properties of such a space station.

SPACE SCIENCE IN A SPACE STATION ERA

In a recent statement entitled, "Space Science Board Assessment of the Scientific Value of a Space Station," the Space Science Board has addressed the issue of the space science need for a space station. It found no need for a space station to support missions addressing high priority science issues for the next two decades. On the other hand, it found that a suitable space station could offer important services to space science in the more distant future.

The Space Science Board realizes that the nation may decide to commit itself to the development of a space station in support of needs and objectives other than or in addition to those of space science alone. The characteristics of such a space station should be carefully determined to conform to the principal activity that it is

intended to support. For example, it is not obvious that a space station optimized as a transportation node for travel between Earth and other solar system objects would also be an entirely suitable platform from which to launch and support science and applications missions. Whatever the eventual properties of such a space station, there will probably be a set of high priority science missions that require orbits and operational support for maximum effectiveness other than those available from that station. If a space station program should be undertaken and it is meant to be useful to space science, the Space Science Board urges that the means to initiate and operate space science missions in a timely fashion and in reasonable accord with priority ordering of those missions be maintained. Ordering of missions would then be determined by scientific priority rather than the nature of the launch or support system required. The Board also urges that the scientific program be structured so as to be protected from delay in space station development or changes in its capabilities.

The Board wishes to make the following specific recommendations and observations.

Scientific instruments that can be deployed in orbits compatible with space station orbits should be flown in optimal scientific orbits and on separate platforms if that is necessary to preserve them from contamination, interference, and degradation of pointing stability and control that may be associated with the manned modules.

If the space station is designed to provide a servicing capability beyond that provided by the shuttle, that capability should allow retrieval of instruments from a wide variety of orbits.

The deployment of a space station designed in part to support space science implies an increase in the level of space science activity above that presently planned. If such a space station is to be utilized effectively, the space station system should be accessible and affordable for scientific use, and there should be a real increase in the level of support for that activity.

A commitment by the nation to long duration human space flight, whether in Earth orbit or beyond, calls for the establishment of a facility for space biological and medical research on the effects of individuals of very long exposure to the "low g" environment. In this sense, the relationship of the life sciences to a space station is a special one.

Thus, a manned space station could eventually provide significant opportunities for a number of disciplines in space science provided there is a commensurate increase in the total level of space science activity. Realization of those opportunities would depend on the extent to which the capability to carry out space science research is kept viable, important experimental and theoretical activity is continued, and new endeavors are initiated while the space station is being developed. After the space station becomes operational, realization of those opportunities would depend on the provision of a sufficient number and variety of flight opportunities, many involving unmanned space craft and flight to regions of space near the Earth and further out in the solar system at distances and locations inaccessible to a manned platform.

Senator GORTON. Dr. Donahue, if in fact the decision were made to deploy a space station by 1992, how would this affect the scientific objectives as presently identified by the Space Science Board?

Dr. DONAHUE. Well, that depends on the impact of—on the budgetary impact. It depends on how well, to what extent the means to launch space science missions and to service them is maintained while the space station is being placed on orbit and to what extent the missions of space science are supported.

If the space science activity is continued at a reasonable level during this period, then there need to be no impact at all and, in fact, as I—it is fairly obvious that once a space station is in place, that it will be better able than the space shuttle, even on an extended mission, to service some of the platforms, some of the free flyers of space science. So it depends on whether we continue to support space science as we have in the past at the traditional fraction of the NASA budget and the means to launch and support

space science missions remains available—a condition that was not, is not the case at the present time.

Senator GORTON. To follow up on that, the Space Science Board has said, and I quote, that:

If a space station is to be utilized effectively, the space station system should be accessible and affordable for scientific use, and there should be a real increase in the level of support for that activity.

Congress appropriated \$843 million for NASA's space science programs for the current fiscal year. What level of funding would be required for those programs for the next fiscal year to support space station scientific use?

Dr. DONAHUE. To support space station——

Senator GORTON. Scientific use. If you were to meet the requirements that you have laid out here and say that there should be a real increase in the level of support for that activity.

Dr. DONAHUE. Well, we were addressing the issue of support for space science activities, service from the shuttle after the shuttle—from the space station after the space station becomes operational.

Senator GORTON. So this would be deferred?

Dr. DONAHUE. We were looking to 1992 in that case.

Senator GORTON. But in proportion, how much greater a support level would be required?

Dr. DONAHUE. Well, that is a tough one. If, indeed, the space station were, as it is advertised, were designed to support and fly all of the space science missions that have been laid out as its target during the next 20 years, then space science missions, as I said, would have to be launched at a rate which is three or four times the present rate of launching.

Senator GORTON. So it would be a substantial——

Dr. DONAHUE. It would be a substantial increase. But remember again that the present budget is not being used to launch and to support missions. It is being used to keep marching armies in place while we wait for the shuttle to become operational. So that factor of three or four certainly does not apply to the budget requirements.

Senator GORTON. Mr. Harter, you stated that effective utilization of a space station would require significant resources for the timely development of instruments and payloads for use on a space station.

You are operating this year on a \$289 million budget for space applications. Speaking not to 1992 but even to 1985, which is when I assume those timely developments would start, how much would be required to support sufficiently space applications activities related to the space station?

Mr. HARTER. Well, I do not believe I can answer in a quantitative sense because we have not attempted to derive those numbers. In the remote sensing area and particularly in the Earth resource area, we feel that too little is being expended and budgeted today for development of future instruments and payloads.

So we do not view the space station itself as necessarily compromising the future of space applications. We see it as perhaps a mechanism for being able to exploit a capability. But whether there is or is not a space station, we feel there is going to have to

be considerable funds expended over the next decade or so to develop the necessary instruments and payloads for the needs of remote sensing.

Now, this whole area is very hazy today, as you might imagine, because of the current administration initiative to transfer both the weather satellite programs and also Landsat to the private sector. And so, frankly, we are quite concerned about just what the future is for developing these instruments and payloads and who is going to do it.

Senator GORTON. So are we, as you have been able to see by our actions with respect to those proposals.

I may have additional questions, but given the nature of the time, if you do not mind, will submit them in writing and ask for the responses to them in that function.

Senator HEFLIN. Dr. Donahue, I appreciate the directness of your testimony. I am aware that the scientific and applications communities are a bit nervous about a space station development.

As I indicated in my opening statement, we need to make sure that we do not have a great capability without healthy science and applications activities to use it.

I want to state publicly that I am committed to seeing that you get strong budgetary support, and I think you will agree that this committee has augmented space science in the past several years.

Now, my question is that if a space station development were to start in fiscal year 1985, how would the science and the applications communities change their long-range mission plans?

Dr. DONAHUE. Well, Judge Heflin, let me say first of all that we are certainly cognizant of and appreciative of the support that this committee has demonstrated for space science during its history. You have come to the rescue of space science repeatedly and very recently, and we certainly do appreciate your efforts.

Could you repeat your question, please?

Senator HEFLIN. If a space station development were to start in fiscal year 1985, how would the science and applications communities change their long-range mission plans?

Dr. DONAHUE. I suspect the answer to that is very little in the beginning. As I said, we are very reluctant to change the missions that we have identified which promise very, very exciting return for space science. And there is a whole host of missions that we have in mind, and they can be serviced and launched very adequately, we think, by the space shuttle which we have at hand. And we certainly would resist, as I again stated in my statement, any temptation to alter these missions to accommodate the promised capabilities of the space station. And our attitude is a consequence of our experience with the space shuttle, which promised many things when it was brought to us in the early 1970's. We are still waiting for those promises to be fulfilled, and in the meanwhile we just are not—we are not launching space science missions.

So I do not think that the decision to go ahead with the space station would change space science plans materially in the near future. Given the assurance that a space station would be on orbit, we certainly would hope that the space agency would modify its

plans for some observatories to take advantage of the ability of the space station to service changeout, repair those satellites.

Senator HEFLIN. Thank you.

Senator GORTON. Thank you.

Thank you, Dr. Donahue, and thank you, Mr. Harter. We appreciate your participation.

[The following information was subsequently received for the record:]

NATIONAL RESEARCH COUNCIL,
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS,
Washington, D.C., November 9, 1983.

Hon. SLADE GORTON,
*Chairman, Subcommittee on Science, Technology, and Space,
Washington, D.C.*

DEAR SENATOR GORTON. Thank you again for inviting me to testify before your Subcommittee. Your letter of November 15th asks two additional questions to which I now respond.

Question. If NASA's planned space station were deployed by 1992, to what extent would its development and utilization stimulate the identification of new space application missions heretofore not identified and how might this space station planning and capability affect the present priority of your planned objectives?

Answer. It is difficult to foresee new space application missions that might arise from the advent of a space station. Advances in space applications should be supported for their own merits without regard to a space station, which may allow us to do things differently and perhaps more effectively.

Question. Space applications activities such as remote sensing and materials processing often have a direct commercial impact on the United States economy. How and to what extent would a manned space station affect space applications activities that would, in turn, have an impact on the United States economy?

Answer. The Space Applications Board has studied the potential benefits of a space station to various applications, i.e., communications, remote sensing, and materials processing in space. In brief, we find little benefit to communications from a space station in the near future. With regard to remote sensing, the participation of man would allow editing and processing of data as they received in a space station. Whether this will have substantial economic benefit would have to be determined. The area of most potential benefit is probably in materials processing, where the presence of an experimenter while the process is active could be very important, especially in the development of unproven processes.

Sincerely,

GEORGE A. HARTER.

Senator GORTON. We will now hear from the Office of Technology Assessment, Mr. Rogers and Dr. Chandler. I gather that we will hear only from Mr. Rogers.

Mr. ROGERS. That is correct, Mr. Chairman.

Senator GORTON. Fine. You may proceed.

STATEMENT OF T. F. ROGERS, DIRECTOR, CIVILIAN SPACE STATIONS ASSESSMENT, ACCOMPANIED BY DR. PHILIP P. CHANDLER, OFFICE OF TECHNOLOGY ASSESSMENT

Mr. ROGERS. Since we have already submitted our statement to the committee, with your permission, and in the interest of conserving time, I would speak to a shortened version thereof.

Senator GORTON. Fine. We would be happy to have you do that. And your entire statement will be included in the record as if read.

Mr. ROGERS. Thank you, Mr. Gorton.

The Office of Technology Assessment is pleased to be offered the opportunity to testify before you today.

I am T. F. Rogers, Director of the OTA Civilian Space Stations Assessment. I have a background in science, engineering, public ad-

ministration and private investing. I have been professionally active in the space area for 26 years and am a member of the National Academy's Space Applications Board.

I am accompanied by Dr. Philip Chandler, the Deputy Director of the OTA project. Dr. Chandler has participated in earlier space assessments. He is particularly knowledgeable about those activities of the Soviet Union that involve its people in space.

The past year has seen discussion quicken regarding the kind of civilian space station, if any, needed to support our national interests in space. In its assessment, the Office of Technology Assessment is studying the issues relating to our obtaining any such space capability. The assessment is fortunate in being advised by an unusually broad and experienced panel. This effort is not complete, so the views expressed here, although carefully considered, must be taken with some reservation.

A wide range of reasons for obtaining such a space station, and various approaches to its design, procurement and use have been advanced. You have had these tangible and intangible reasons alluded to here by Victor Reis and James Beggs.

Given these reasons, NASA has begun to focus on defining and obtaining the elements of a space station in what it describes as "the next logical step in space." It favors a large and sophisticated ensemble of elements employing a great deal of new technology and favors procuring it in the classical NASA fashion.

The total cost to the Federal Government of obtaining and operating such a space station would almost certainly be \$20 billion, and in the nature of such things could approach \$30 billion, by the end of this century.

Before endorsing such a proposal, therefore, it is most important that we have a very clear understanding of specifically how many of what goals are to be addressed, and what needs are to be met, when, by what kind of space elements.

It is fundamental to the consideration of the issues to appreciate that there is no single thing called the space station. I would like to repeat that, Mr. Chairman. There is no single thing called the space station. There is, rather, a large number of potential space stations made up of various combinations of characteristics: Orbit, on-orbit lifetime, volume, power, communications, and so forth. Each characteristic chosen would have a particular value taken from a fairly wide range.

Given the space technology now available, and that which has received extensive study, the number of personnel that could be accommodated range from, say, 0 to 10, the pressurized volume from nothing to 10,000 cubic feet, the power available to users up to 200 kilowatts and so on.

Accordingly, the cost could be as low as \$5 million for the smallest passive platform to hundreds of millions of dollars for a shuttle orbiter modified to allow extended lifetime in orbit, to tens of billions of dollars for sophisticated, essentially permanent elements that could support a large human crew. Thus, the particular array of space infrastructure elements that NASA now aspires to is only one of a very large number of possible arrays of these elements.

Mr. Chairman, space infrastructure is simply that, infrastructure. Its availability allows certain space-related goals to be ad-

dressed and objectives to be accomplished. It is, if you will, a stepping stone to some end.

In response to your request for information and alternative approaches, we have prepared a preliminary listing of some combinations of infrastructure elements that have received considerable study: Their fundamental characteristics, the needs which their capabilities should be able to meet, their capital cost, and the time that it should take to obtain them. This listing accompanies our written testimony.

The characteristics of the infrastructure now favored by NASA reflect the judgment of its leadership as to what space activities it could be used to support. Unfortunately, NASA's selection of these activities took place in the context of an inhibited study. This study simply identified scores of ongoing and planned space activities.

Mr. Chairman, the civilian space-related goals of the United States should be such as to command widespread attention, have great inherent scientific interest, force the cutting edge of technology development, have relevance to global issues, prompt international cooperation, promise both challenges to and the easing of the human condition, and involve major participation of our private sector.

But over the past decade no offices of the executive branch have urged NASA to study and articulate such a national agenda of goals—long-term, inspiring goals—for the purpose of stimulating national debate about their acceptance. And in its absence, OTA concludes that it is simply not possible to judge objectively whether or not the suggested infrastructure elements are truly appropriate and worth their substantial cost.

Parenthetically, and OTA has been making this point for over a year, we know of no broad and continuing professional study efforts, the products of which could be used by our leaders to see that the American public has the opportunity to consider and help adopt space-related goals that address important and long-term scientific, exploratory, and especially, cultural, economic, social, and political ends.

Absent agreement upon such a fundamental agenda, it is not clear that we should even begin to obtain such an expensive space infrastructure. The very act of allocating such a large and long-term stream of public dollars in this fashion could perhaps foreclose our ability to provide funds, imagination and administrative leadership to address exceptionally important national space-related goals.

It can be argued that any request to commence work on the large and costly space station that NASA now apparently favors be held in abeyance until a comprehensive national, publicly supported, civilian space program is identified. However, we should remember that the future is always the enemy of the present. Therefore, NASA might be asked to examine whether or not there already exists today some generally accepted goals that could be pursued with some long-term space infrastructure elements. For instance, the science community and the private sector might be able to agree with NASA upon some important basic research objectives (perhaps in the life sciences and the material sciences) and a limited array of modest space assets that would be appropriate for at-

taining these specific objectives. Through both important international cooperation and private-sector commitments, the cost of this infrastructure to our Federal Government could perhaps be kept acceptably low. The Congress might consider prompting the executive branch to study such possibilities.

In addition, the Congress might also consider encouraging other countries to play a major cooperative role in the discussion of the needed space infrastructure and the provision of infrastructure elements.

As well, the Congress might consider encouraging major participation of our private sector in privately funded development and use of space infrastructure elements.

NASA's leaders could then devote more attention to orchestrating the effects of many countries with growing space interests and capabilities and the vigorous encouragement of our private sector.

The past half year has seen a resurgence of military interest in defense against ballistic missiles. This interest could soon prompt sharply increased research and development programs in the space area. Unless our publicly funded civilian space programs have sufficient challenge, NASA and the space industry could well yield up too many of its brighter and more competent professionals to military space work. And this could presage the crumbling of a fundamental space posture of the United States; that is, that we should have vigorous, publicly supported, space programs in both the civilian and military areas.

Finally, there is the matter of the Soviet Union's continued emphasis on keeping some of its men and women in space and its continually increasing capability to support them there and to broaden their areas of inspace study and work.

We have the sense that this important Soviet commitment is proceeding without great notice on the part of our general public. By the end of this month, therefore, we expect to be able to release a technical memorandum entitled "Salyut—Soviet Steps Toward Permanent Human Presence in Space," a draft of which we have already delivered to the committee.

To recapitulate quickly, Mr. Chairman, the energetic study and public discussion of a civilian space station is serving a very useful purpose. It is forcing us to reexamine our civilian space experience, institutions and physical assets, our manner of acquiring and using these assets, and the influence of the space interests of other countries and our own private and military sectors upon our publicly funded civilian space activities.

Most importantly, it motivates us to reexamine our fundamental civilian space goals. Today we have far too fuzzy a vision of those goals. Without a clearer, more thoughtful vision, how can we expect consensus; and without consensus, how can we rationally make long-term commitments? Arriving at such a consensus should be our first order of business.

This completes my statement, Mr. Chairman. Thank you for inviting us here today.

Mr. ROGERS. We trust that the OTA assessment will be valuable to the committee when it is available next spring.

Senator GORTON. There is no question that it will, and the insights you have already given to us are extremely valuable, and we are continuing to search for a solution.

You mentioned that you will soon release a technical memorandum on the Soviet Salyut space station program. Can you at this point tell us anything about the direction and the future plans of that Soviet program? And can you also compare NASA's plans for an initial space station capability to the present Salyut capability and the capabilities that the programs are likely to have in 1992, either of you?

Mr. ROGERS. It would seem to me that the first question is better addressed by Dr. Chandler.

Senator GORTON. Fine.

Dr. CHANDLER. Thank you, Mr. Chairman. Let me point out some differences between the way the Soviets have proceeded and the way the United States proceeds.

In the first place, it has been stated at the highest levels in the Soviet Union that it is a fundamental goal of the U.S.S.R. to expand human habitation out from the Earth into the solar system. Former President Brezhnev, for example, has been quoted as saying that permanently manned space stations with interchangeable crews will be mankind's pathway into the universe.

Soviet acceptance of what can be characterized only as a long-range goal contrasts sharply with the absence of such formally recognized goals for the U.S. program.

Indeed, if I might add, the most spectacular U.S. accomplishments—the Apollo voyages to the Moon—proved the point precisely because they were dead ends, not part of a grander design beyond themselves.

The other major difference of the two countries' space programs lies in the approach to their space capabilities. Whereas the United States tends to advance from one space capability to the next in what one might call quantum leaps, the Soviet Union has tended to modify and adapt technology already in hand, thereby increasing its capabilities in an apparently step-by-step or incremental fashion.

By thus relying on systems flight proved in earlier space projects, the Soviets may have been able to restrain costs and minimize the time spent in development and construction. Thus, the current Soviet orbital station, Salyut 7, is only the latest in a series marked by steady, if unspectacular, improvement from model to model.

As far as what the Soviets are likely to do in the future, Mr. Chairman, the major initiative to be expected and, we think, soon, is a modular space station built either out of Salyut-class modules and others of similar size and capabilities or else out of larger next generation modules.

But if they are to succeed in the latter course, they will also have to succeed in bringing to operational status a large, expendable booster which will be capable of lofting such modules into orbit.

Finally, the Soviets are reported to be developing two kinds of reusable space vehicles—a small space plane and a larger heavy lift shuttle similar to the U.S. shuttle but perhaps more capable.

If they succeed in bringing all of these initiatives to fruition, then they will certainly have, well, one might call it a military-in-

dustrial complex in orbit, and also a staging base for future missions outward.

Senator GORTON. Thank you.

Mr. ROGERS. I would like to make one observation, Mr. Chairman, that might be helpful about the desired capability of the present NASA initial operating capability [IOC] design and the present capability of the Salyut 7 station.

We must keep in mind that, in the civilian space area, the United States has spent some \$200 billion—adjusted 1983. We have a lot of experience, and we have a lot of assets. We know how to modify these assets in a fairly straightforward fashion.

If we were to ask ourselves: Could we duplicate the volume, the safety, the orbital occupancy, the communications capacity, the power, all of the fundamental characteristics of the present Salyut space station, its stability, thermal control, whatever; we think, to a good enough first approximation, we could say that it would cost about a third of the present estimated cost of the NASA IOC capability.

Now, the NASA infrastructure would have a great deal more capability, but your question was what would be the comparison between what we would have and what the Soviet Union has now. That is as close as I can come to answering your question.

Senator GORTON. Thank you.

You indicated in your testimony that we could have the smallest passive platform for \$5 million, an extended duration orbiter for several hundred million dollars, or a very sophisticated, essentially permanently manned presence in space for billions of dollars.

What are the major drivers of the cost or considerations that provide each more advanced level of space presence and cost?

Mr. ROGERS. I would make two or three introductory observations and then get to the easier part, which is the technical.

Cost to whom, Senator? We always assume in these discussions, without giving it a second thought, that the public purse will provide all the money—that the Federal Government will bear the entire cost. So my first observation to you would be that if we could indeed involve other countries, cooperatively, in our activities—and many of them, clearly, as revealed in OTA's discussions with their representatives, would certainly like to be discussing with NASA what they could do, and would be prepared to do—it would put a lesser burden upon our Federal financial demands.

Second, we have the whole private sector that could be looked to to develop, to finance and to provide large pieces of space infrastructure. But, so far as we can tell, they are not being prompted to do so. They are not being encouraged specifically to do so. Some of them are beginning to give serious thought to doing so anyway, and we will see what develops.

The third thing we would say is that there is a general sense—and this is somewhat premature for the moment, because our assessment of this topic is not complete—but there is a general sense that, if NASA were determined to do so, it could change some of the practices that it now employs for the procurement of sophisticated technology and the procurement of the services to support that technology. We have learned a great many lessons in the past 20 years, and it is not at all clear that we should go about procur-

ing space technology now and in the future the way that we did during the Apollo and shuttle eras. I cannot really go beyond this point. We are in midstream in our studies. But that is the sense that we are obtaining from talking to a very wide selection of people in today's space industry and in the sophisticated aircraft and the sophisticated surface construction industry.

The final observation that I would make is that when it comes to the actual nuts and bolts of infrastructure, space infrastructure (always setting aside the surface support cost) it almost comes down to whether or not you have people there. If you have people there, you must pay a great deal more attention to all of the life-support services you need. Sophisticated "passive" equipment must be given some attention, of course, in that regard, too. But putting human beings up there certainly is more costly.

Having large amounts of power—there is a debate about how much a watt costs in orbit, but we have seen estimates for very large amounts of power of as much as \$10,000 a watt. To those who purchase their electricity at the Earth's surface, that is a rather stunning number, but that is about what it costs in space. And that means that if you want a kilowatt in orbit, about enough to run an electric toaster, it is going to cost you \$10 million. And the numbers that we have talked about here and heard others talk about here today, will bring you quickly up to the range of hundreds of millions and even billions of dollars.

So we would say: Human beings, power, and after that, volume and structure.

[The statement and answers to questions of the committee follows:]

STATEMENT OF T. F. ROGERS, PROJECT DIRECTOR, ACCOMPANIED BY DR. PHILIP P. CHANDLER, DEPUTY DIRECTOR, SCIENCE, TECHNOLOGY, AND INNOVATION PROGRAM, OFFICE OF TECHNOLOGY ASSESSMENT

The Office of Technology Assessment (OTA) is pleased to be offered the opportunity to testify before you today on the subject of "Civilian Space Station."

I am T. F. Rogers, Director of the OTA space stations assessment. I have a background in science, engineering, public administration and private investing, have been professionally active in the space area for 26 years and am a member of the National Academies' Space Applications Board.

I am accompanied by Dr. Philip Chandler, the Deputy Director of the OTA project. Dr. Chandler has participated in earlier space assessments. He is particularly knowledgeable about those activities of the U.S.S.R. that involve its people in space and the assets it uses to transport and support them in orbit.

The past year has seen discussion quicken regarding the kind of civilian space station, if any, needed to support our national interests in space. Unfortunately, this discussion has tended to focus, rather early, on "go/no-go" conclusions regarding a particular NASA design.

In its assessment, the Office of Technology Assessment is studying the issues related to our obtaining any such space capability. The assessment is fortunate in being advised by an unusually broad and experienced Panel under the Chairmanship of Robert Charpie, the President of the Cabot Corporation. This effort is not complete, so that the views expressed here, although carefully considered, must be taken with some reservation.

A wide range of reasons for obtaining such a space station, and various approaches to its design, procurement and use, have been advanced.

The reasons encompass important intangibles prompted by considerations of exploration and adventure, energizing of innovation, and the national pride in ourselves that captured our imagination, and that of others, in the first two decades of the space age—such intangibles as:

exhibiting continued space leadership,

exhibiting high technology prowess, encouraging international cooperation, maintaining a vigorous government in-house space engineering capability, extending human presence in space, promoting commercialization of space, and enhancing national security.

They encompass, as well, more tangible ones such as:

the conduct of experimental studies in scientific areas not presently available to us,

the assembly and checkout of large and sophisticated space structures, the initial testing, servicing, and repair of equipment and free-flyers, the provision of new commercial-industrial services, the staging of long distance, long duration space flights, the improvement of overall surface-space transportation efficiency, the provision of a depot for human resources, fuel, and equipment, the reduction of the cost of space activities, and the initiation of personal travel into space.

Given these reasons, with its great success in the Apollo program well behind it, and with the Shuttle already having reached useful operational status, NASA, in concert with our aerospace industry, has begun to focus on defining and obtaining the elements of a space station—in what it describes as: “the next [major] logical step in space.” At present, it favors a large and sophisticated ensemble of elements employing a great deal of new technology, and favors procuring it in the “classical” NASA fashion. Under presently foreseeable circumstances, the total cost to the Government of obtaining and operating such a space station would almost certainly be \$20 billion (1984) and, seemingly in the nature of such things, could approach \$30 billion (1984) by the end of this century, i.e., an average of as much as some \$2 billion/year.

Before endorsing such a proposal, one should ascertain the value to the country of this particular expenditure, at this time, and in this fashion, relative to the value of other activities seeking Federal outlays. Certainly it is most important that we have a very clear understanding of specifically how many of what goals are to be addressed and what needs are to be met, when, by what kind of space elements; and who can be expected to benefit from their use and, therefore, should be expected to share in their design and development, and in meeting their cost.

It is fundamental to the consideration of the issues surrounding any “Civilian Space Stations” to appreciate that there is no single thing called “The” space station. There is, rather, a large number of potential “space stations” made up of various combinations of characteristics. That is, any space station—or long-term space “infrastructure,” to use an expression more widely used on Earth—could be defined by reference to the following in-space characteristics:

- Orbit,
- On-orbit lifetime,
- Volume,
- Stability,
- Thermal control,
- Safety,
- Power,
- Communications,
- Local transportation,
- Storage capacity, and

Human accommodations: safe and sanitary living and working conditions for any men and women in orbit on an intermittent or full-time basis

(And, as well, surface support characteristics).

Each characteristic chosen would have a particular value taken from a fairly wide range. Given the space technology now available, and that technology not yet available but which has received extensive study, it would appear that the number of personnel that could be accommodated range from 0-10; the pressurized volume from 0-10,000 cubic feet; the power available to users up to 200 kilowatts; etc. Accordingly, the cost could be as low as \$5 million for the smallest passive platform, to hundreds of millions of dollars for a Shuttle Orbiter modified to allow a considerably extended lifetime in orbit, to tens of billions of dollars for sophisticated, essentially permanent, elements that could support a large human crew and a wide range of space activities. Thus, the particular array of space infrastructure elements that NASA now aspires to is only one of a very large number of possible arrays of these elements. Interestingly, it is different from the one which NASA favored a year ago; a year from now the choice could differ from today's.

Mr. Chairman, I must now address the most basic problem in the civilian space area that affects the consideration of any long-term civilian space infrastructure.

Space infrastructure is simply that—infrastructure. Its availability allows certain space-related goals to be addressed and objectives to be accomplished. It is, if you will, "methods and means," or a "mechanism" for, or a "stepping stone" to some end.

In response to your request for information and alternative approaches, we have prepared a preliminary listing of some combinations of infrastructure elements that have received considerable study, their fundamental characteristics, the needs which their implied capabilities should meet, their estimated capital cost, and the estimated time that it should take to obtain them. This listing accompanies our written testimony. It should be understood that it is far from final; rather, it is simply instructive. Undoubtedly, some of our estimates will be challenged and changed (in some cases they reflect subjective judgments), but we believe that they are sufficiently accurate and useful for the purposes of discussion.

The characteristics of the infrastructure now favored by NASA reflect the judgment of its leadership as to what space activities it could be used to support. Unfortunately, NASA's selection of these activities took place in the context of an inhibited and (perhaps therefore) relatively uninspired study. Essentially, this study simply identified scores of on-going activities, i.e., "missions" and already planned space activities that (they hope) would receive eventual approval.

The civilian space-related goals of the United States should be such as to command widespread attention; have great inherent scientific interest; force the cutting edge of technology development; have relevance to global issues; prompt international cooperation; promise both challenges to, and the easing of, the human condition; and involve major participation of our private sector.

But over the past decade no offices of the Executive Branch have urged NASA to study and articulate such a national agenda of goals for the purpose of stimulating national debate about their acceptance. To our knowledge, there is no comprehensive and thoughtful list of goals—at least outside of the space science and exploration areas. And, in its absence, OTA concludes that it is simply not possible to judge, objectively, whether or not the suggested infrastructure elements are truly appropriate and worth their substantial cost.

Parenthetically—and OTA has been making this point for over a year—we know of no broad and continuing professional study effort, the products of which could be used by our leaders to see that the American public has the opportunity to consider and help adopt space-related goals that address important and long-term scientific, exploratory, and, especially, cultural, economic, social, and political ends.

Absent agreement upon such a fundamental agenda, it is not clear that we should even begin to obtain such an expensive space infrastructure. There is little important external demand, and no convincing argument, that it be obtained in a hurry. And the very act of allocating such a large and long-term stream of public dollars in this fashion could well restrict—and perhaps even foreclose—our ability to provide funds, imagination and administrative leadership to address exceptionally important national space-related goals, much less alternative goals for public investment.

In these circumstances, it can be forcefully argued that any request to commence work on the large and costly "space station" that NASA now apparently favors be held in abeyance until a comprehensive national, publicly supported, civilian space program is identified.

However, we should remember that "the future is always the enemy of the present." Therefore, during the time required to study and debate a set of long-term national space goals, NASA might be asked to examine whether or not there already exist, today, some generally accepted goals that could be pursued with some long-term space infrastructure elements that amount to much less of a commitment than the suggested "manned space station". For instance the science community and the private sector might be able to agree with NASA, first, upon some important basic research objectives (perhaps in the life sciences and materials sciences areas), and, second, upon a limited array of modest space assets and surface and space research activities that would be appropriate for attaining these specific objectives. Through both important international cooperation and private-sector commitments, the cost of this infrastructure to our Federal Government could perhaps be kept acceptably low. The Congress might consider prompting the Executive Branch the National Academy of Sciences, and our private sector to begin to study, together, such possibilities.

In addition, the Congress might also consider encouraging other countries to play a major cooperative role in the discussion of the needed infrastructure, and the provision of compatible, complementary space infrastructure elements so as to address

space goals of agreed-upon international importance. As well, the Congress might consider encouraging major participation of our private sector in privately funded development and use of space infrastructure elements. NASA's leaders could devote more attention to orchestrating the efforts of many countries with growing space interests and capabilities, and the vigorous encouragement of our private sector—both the present large and mature sections thereof, and small, new, and entrepreneurial sections as well. Such a course would allow more of NASA's scientists and engineers to concentrate upon what they do well: basic and applied space research and exploration, and the development of that advanced technology required for the effective conduct of such research and exploration.

We must also keep in mind that the Shuttle itself could be used to obtain information and experience relevant to the design and use of any eventual long-term space infrastructure. In particular, the mixes of sophisticated human beings and sophisticated machines appropriate for different space tasks should be carefully studied.

Under any circumstances, of course, we must not again allow our "core" space activities in science, applications and technology development to become unduly burdened by "taxes" levied upon them to pay for unforeseen costs in such very large hardware programs.

Mr. Chairman, there are two other matters that merit your attention.

The past half-year has seen a resurgence of military interest in defense against ballistic missiles. This interest could soon prompt sharply increased research and development programs in the space area. Many scientists and engineers will, naturally, be attracted to the resulting opportunities to develop very advanced technology. This possibility clearly suggests another important reason for our civilian space leaders to lay the base for sound, broad-ranging, civilian space goals. Unless our publicly-funded civilian space program has sufficient challenge—and not only technological challenge—NASA and the space industry could well yield up too many of its brighter and more competent professionals to military space work. This possibility, in turn, could perhaps presage the crumbling of a fundamental space posture of the United States, i.e., that we would have vigorous, publicly-supported, space programs in both the civilian and military areas.

Finally, there is the matter of the U.S.S.R.'s continued emphasis on keeping some of its men and women in space, and its continually increasing capability to support them there and to broaden their areas of in-space study and work. We have the sense that this important Soviet commitment to enlarge the capability of that part of its space program that involves its people in orbit is proceeding without great notice on the part of our general public. Therefore, we have concentrated some of our assessment resources on understanding and describing these efforts. By the of the month we expect to be able to release a Technical Memorandum entitled *Salyut—Soviet Steps Toward Permanent Human Presence in Space*, a draft of which we have already delivered to the Committee. I understand that this Technical Memorandum will be printed in the hearing record.

To recapitulate quickly, Mr. Chairman:

The energetic study and public discussion of a "civilian space station" is serving a very useful purpose. It is forcing us to re-examine our civilian space experience, institutions, and physical assets; our manner of acquiring and using these assets; and the influence of the space interests of other countries and our own private and military sectors upon our publicly funded civilian space activities.

Most importantly, it motivates us to re-examine our fundamental civilian space goals.

What we should expect of ourselves, and what others should expect of us, is that our space goals continue to encompass the useful, the stimulating, the grand.

Today, we have far too fuzzy a vision of these goals. Without a clearer, more thoughtful, vision, how can we expect consensus? And without consensus, how can we rationally make long-term commitments? Arriving at such a consensus should be our first order of business.

This completes my statement, Mr. Chairman.

Thank you for inviting us here today. I trust that the completed OTA assessment will be valuable to the Committee when it is available next spring.

Attachment.

ALTERNATIVE APPROACHES FOR REALIZING SPACE INFRASTRUCTURE

The accompanying Tables are designed to assist in evaluating alternative approaches for obtaining space infrastructure that could, in varying degree, satisfy various needs or requirements that have been expressed for such infrastructure.

The Tables include those elements of a so-called civilian space station envisioned in current NASA planning.

Typical options (of the many that could be examined) are shown in Table 1 for three groups of possibilities. First, the present Shuttle Orbiter and its possible modifications for extended stays on orbit (Extended Duration Orbiter—EDO) are listed. Second, one version of the Spacelab developed as a free-flying inhabited core vehicle is examined. Finally, the NASA-envisioned space station is given: both the initial operational capability (IOC) version (1991–1992) and a mature, fully-developed infrastructure (1996–2000).

The parameters for each option that may be used for rough comparative purposes are:

1. Approximate date of availability, assuming that a "go-ahead" were given in 1985;
2. Cost (in fiscal year 1984 dollars) to produce the capabilities shown. Some options depend on existing hardware so the costs do not reflect similar proportions of development and production efforts for the various options;
3. Characteristics—several design parameters and sizing factors that provide the bases for infrastructure capabilities;
4. Capabilities—the types of functional activities that the listed infrastructure should be capable of supporting, and the degree to which these activities might be accomplished.
5. Responsiveness of a given infrastructure to the various reasons put forward for having a "civilian space station," including any extended presence of human beings in space.

If great and long-range space activities (such as say, for instance, the establishment of a lunar base or the return of materials from the asteroids or Mars) come under consideration, they would appear to be achievable using a sophisticated orbital transfer vehicle coupled with on-orbit assembly, checkout, launch, and recovery. The one option listed in Table 1 with one of these capabilities is the NASA fully developed infrastructure.

Table 2 presents information on proposed "free-flyer" space platforms that could be used in conjunction with, and serviced by, any of the options listed in Table 1. In this way, additional capabilities could be added to the infrastructures given in Table 1 for the cost of buying and incorporating these platforms in the overall infrastructure.

Interest within the private sector indicates that it may be able to provide some of the platform elements of a space infrastructure; in Table 2, both MESA and LEASE-CRAFT are proposals of United States aerospace companies (Boeing Aerospace Company and Fairchild Space Company, respectively). Among others, a new private enterprise, Space Industries, Inc., is studying a module that would be a long-duration industrial facility suitable for manufacturing (materials processing) in space. While it is too early for details of design and cost to have been revealed by the company, the module apparently would be tended by a crew while the Shuttle was in its vicinity. As with the others, it could be in place prior to the planned launching of a NASA-proposed space station. In addition, both Teledyne-Brown and Ball Aerospace Systems are studying the possibility of providing facilities that would be mounted in the Shuttle's cargo bay and used for experiments.

Another alternative not specifically listed in the tables is the use of the Shuttle external tank (ET) as an infrastructure component. Conceivably, the ET could be used for fuel and materials storage, as a pressurized module, for mechanical structure, and as a safe haven during emergencies. A principal advantage is the low in-orbit cost. Relative to the other alternatives, it has received modest study and is therefore mentioned here only.

Some cautions should be noted in the interpretation of this information. These are preliminary descriptions of the options and estimates of their capabilities. All estimates are a rough order of magnitude with quantities being presented to only one significant figure. Capabilities have been described by qualitative adjectives; quantitative descriptions would be premature at present. In the fifth section in response to the reasons advanced for a space infrastructure, the comparisons are qualitative and subjective in nature and are presented simply to bring these factors to the attention of the reader. Future revision is possible as issues become more sharply focussed and designs given more study. For instance, as a particular item, the Spacelab option of Table 1 is only one of several that have been put forward; one by the European Space Agency (ESA) countries could definitely augment international cooperation if it were to be implemented.

TABLE 1.—COMPARISON OF SOME OPTIONS FOR EARLY ORBIT LONG TERM INFRASTRUCTURE

System	Shuttle orbiter	Extended duration orbiter: Phase 1	Extended duration orbiter: Phase 2	Spacelab (developed as permanent infrastructure)	NASA infrastructure aspirations	
					Initial operational capability	Mature, fully developed
Data available: New, or approximate, assuming start in 1985	Now	1988	1990	1990	1992	1996-2000.
Cost: Billions of fiscal year 1984 dollars	None	0.1	0.4	2	8	20.
Characteristics:						
Power to users (MW)	7	7 (less if over full stay time).	20	10	60	200.
Pressured volume (l + ^a)	2,000	2,000	5,000 (with spacelab habitat).	5,000	6,000	10,000.
Crew size	6	5	6	3	8	10.
Miscellaneous:	Can accept spacelab.	No new technology	New technology required	Limited crew accommodations.	Orbital maneuvering vehicle plus 2 freeflying unpressurized platforms.	Reusable orbital transfer vehicle plus several more platforms.
Capabilities:						
Time on orbit	7 days	20 days	50 days	Unlimited (60-90-day resupply).	Unlimited (90-day resupply)	Unlimited (90-day resupply).
Laboratories for:						
Life Sciences	Yes	Yes	Yes	Yes	Yes	Yes.
Space Science/applications	Very modest	Very modest	Very modest	Limited	Extensive	Extensive.
Materials science	Some	Some	Moderate	Moderate	do	Do.
Technology development	Modest	Modest	Some	do	do	Do.
Observatories	No	Limited	Limited	Limited	do	Full.
Data/communication node	No	No	No	No	Yes	Yes.
Servicing of satellites	Modest	Modest	Modest	Modest	Extensive	Full.
Manufacturing facility (materials processing)	No	No	Limited	Limited	do	Full.
Large structure assembly	No	No	No	do	Moderate	Extensive.
Transportation node	No	No	No	No	do	Do.
Fuel and supply depot	No	No	No	No	No	Yes.
Response to reasons for space infrastructure:						
Maintain U.S. space leadership and technology capability	No	Little	Some	Modest	Considerable	Extensive.
Respond to U.S.S.R. space activities	No	Weak	Weak	do	Strong	Very strong.
Enable long-term human presence in space	No	Little	Modest	Considerable	Extensive	Extensive.
Attention-getting heroic public spectacle	No	Weak	Weak	Modest	Modest	Modest.
Extended international cooperation	do	Modest	Potentially moderate	Potentially moderate	Potentially considerable	Potentially extensive.
Promote U.S. commercialization of space	No	Modest	Modest	Indeterminate	Indeterminate	Indeterminate.
Maintain vigorous NASA engineering capability	No	Negligible	Negligible	Little	Extensive	Extensive.
Enhance national security broadly defined	No	do	do	do	Indeterminate	Indeterminate.
Space travel for nontechnicians	Little	Little	Little	do	Some	Some.

TABLE 2.—SPACE PLATFORMS THAT COULD BE SERVICED BY SHUTTLE OR ANOTHER SPACE INFRASTRUCTURE ELEMENT, THE ORBITAL MANEUVERING VEHICLE

System	Unpressurized coorbiting platforms (serviced with extravehicular activity)				Pressurized platform (serviced internally while docked) European modified spacelab
	SPAS	MESA	Leasecraft	EURECA	
Date available: now, or approximate assuming start in 1985.	Now	Now	1986	1987	1989
Cost: billions of fiscal year 1984 dollars.	0.005	0.01	0.2	0.2	0.6
Characteristics:					
Power to users (kW)	0.6	0.1	6	2	6
Pressurized volume (ft ³)	None	None	None	None	3,000
Crew size	None	None	None	None	3
Miscellaneous	3,000 lb payload	200 lb payload	10,000 lb payload	3,000 lb payload	20,000 lb payload
Capabilities:					
Time on orbit	10 days	8 months	Unlimited	6 months	Unlimited
Laboratories for:					
Life Sciences	No	No	No	No	Modest
Space science/applications	Very limited	Very limited	Modest	Modest	Modest
Materials science	Very limited	No	Modest	Modest	Moderate
Technology development	No	No	Little	Little	Modest
Observatories	No	No	modest	Modest	Moderate
Data/communication node	No	No	No	No	No
Servicing of satellites	No	No	No	No	No
Manufacturing facility (materials processing)	No	No	Considerable	Modest	Considerable
Large structure assembly	No	No	No	No	No
Transportation node (assembly, checkout and launch)	No	No	No	No	No
Fuel and supply depot	No	No	No	No	No
Response to reasons for space infrastructure:					
Maintain U.S. space leadership and technology capability	No	No	No	No	No
Respond to U.S.S.R. space activities	No	No	No	No	Modest
Enable long-term human presence in space	No	No	No	No	No
Attention-getting heroic public spectacle	No	No	No	No	No
Extended international cooperation	Yes	No	No	Yes	Yes
Promote U.S. commercialization of space	Indeterminate	Yes	Yes	Indeterminate	Indeterminate
Maintain vigorous NASA engineering capability	No	No	No	No	No
Enhance national security, broadly defined	No	No	No	No	No
Space travel for nontechnicians	No	No	No	No	No

PROPOSED ANSWER TO EXPECTED QUESTION RE SOVIET INTENTIONS IN SPACE

"What are the future intentions and plans of the Soviet Union, and how do they compare with those of the United States?"

The Soviet Union's venture into space differs in two major respects from that of the United States. In the first place, it has been stated at the highest levels in the Soviet Union that it is a fundamental U.S.S.R. goal to expand human habitation outward from Earth into the solar system. Former President Brezhnev has been quoted as saying that "permanently manned space stations with interchangeable crews will be mankind's pathway into the universe." Soviet acceptance of what can be characterized only as a long-range goal contrasts sharply with the absence of such formally recognized goals for the U.S. program. Indeed, the most spectacular U.S. accomplishments, the Apollo voyages to the moon, prove the point: the Apollo program was a dead end, not part of a grander design beyond itself.

The other major point of difference in the two countries' space programs lies in their approach to the development of space capabilities. Whereas the United States tends to advance from one space capability to the next by quantum leaps, the Soviet Union tends to modify and adapt technology already in hand, thereby increasing its capabilities in an apparently more evolutionary or incremental fashion. By thus relying on systems flight-proved in earlier space projects, the Soviets may have been able to restrain costs and minimize the time spent in development and construction. Thus, the current Soviet orbital station, Salyut 7, is only the latest in a series marked by steady, if unspectacular improvement from model to model.

In accordance both with their long-range plan and the development of their space capabilities to date, the Soviets' next major initiative is expected to be the construction of a much larger, modular, space station, either out of Salyut-class modules and others of similar size and complexity, or out of larger, next-generation modules. Success in the latter course, however, will depend on concomitant success in bringing to operational status a large expendable booster, currently under development and expected to be test-flown in the next year or two. This booster, with a thrust of some

400,000 lbs, even larger than the now defunct U.S. Saturn V, would allow much larger modules to be lifted to low Earth orbit.

In order to increase their flexibility of operation to and from low-Earth orbit, the Soviets are also reported to be developing two re-usable spacecraft, a light space plane and a heavy-lift shuttle-type vehicle. If they succeed in bringing all these plans to fruition, the Soviets will have achieved a very capable space infrastructure which could be used, not only as a military-industrial complex in orbit, but also as a base camp for future manned expeditions to the Moon.

QUESTIONS OF THE COMMITTEE AND THE ANSWERS THERETO

Question. In your testimony, you have said that before we begin making large expenditures for space infrastructure, NASA might examine whether or not there already exists some generally accepted goals that could be pursued only with the use of some long-term space infrastructure elements.

(a) In your opinion, what generally accepted goals have been identified by the potential users of a space station?

Answer. There were none. "[T]he potential users of a space station" were not asked to identify, nor did they identify, any such "goals".

The sense in which the word "goals" was used in the statement relative to the United States' publicly-supported civilian space program connotes "long-term," "strategic" and "nationally agreed upon". That is, such goals would essentially define, in contemporary terms, the basic interests of the American public in the civilian space area—interests that could reasonably be expected to be invariant with time throughout, say, the next quarter of a century.

In contrast, most of the "uses" identified by NASA (and there are well over 100 of them) that could employ a so-called civilian space station envision, in effect, the employment of certain assets (including, in some instances, people) and the conduct of activities in space to make observations, to conduct experiments, to undertake commercial and industrial works, and to support all of these activities in a more efficient manner than is the case today. All of these "uses" could be grouped under several "objectives" that would address one or more national "goals".

Semantics aside, we are reasonably confident that our government, university and commercial-industrial private sector communities, together, could identify some specific space-related basic and applied research objectives that would profit from having available some modest, longer-term, people-supporting elements of space infrastructure. Our statement suggests that, for instance, such objectives might be sought in the life sciences and materials sciences areas.

Question. In your testimony, you have listed a number of tangible and intangible reasons for obtaining a space station. When a decision is ultimately made on whether or not we should develop a space station, how much emphasis should be placed on the capability of a space station to stimulate and identify new uses and missions that heretofore have not been identified?

Answer. The presence and use of almost any kind of long-term, in-orbit infrastructure could contribute to the discovery of "new uses and missions that hitherto have not been identified." This fact alone, however, in no way dictates either the particular constellation of such assets that would be most likely to stimulate innovation or the resulting cost that the public would be asked to meet. Nor is it clear that investing in such infrastructure rather than in other space assets or activities would be a superior way to prompt such stimulation. Accordingly, the "emphasis" that could be placed on unknown future uses must remain an incremental value of any selected infrastructure, rather than a major factor for having the structure itself.

Great science requires that the truly unexpected be discovered and understood, and great industrial advances require that truly novel inventions be made and employed in an on-going, large-scale manner. While, by definition, we cannot yet imagine any such unexpected discoveries and novel inventions in the space area, we all expect that they will be made in such new and relatively unexplored and unexperienced circumstances—and our scientists, engineers, inventors, and entrepreneurs should all be alert to their possibility and importance.

However, again by definition, it is not possible to expect, let alone plan for, the specifics of any such discoveries and inventions, and it therefore is asking the impossible of any space infrastructure designers to incorporate characteristics in the infrastructure elements that, in and by themselves, could be expected directly to enhance the likelihood that such discoveries and inventions will be made.

To encourage this likelihood, our space program could emphasize: (a) easing access to space by reducing the cost of traveling to and from space, and residing and working there, (b) opening up the opportunity to be directly involved in space activities

to a much broader cross-section of the general public, and (c) supporting basic and applied in-space research of interest to our scientists and engineers, and to those businesses which are involved in supporting such research activities.

Question. According to your testimony, there is no mechanism by which the "American public has the opportunity to select space-related goals that address important and long-term scientific, exploratory, cultural, economic, social, and political ends."

(a) What purpose would a goal-selection mechanism or process such as this serve?

(b) How would a goal-selection process such as this be most effectively institutionalized?

Answer. With the demise of the National Aeronautics and Space Council in 1973, there is no longer any broadly representative professional body charged with providing thoughtful guidance on national space policy on a continuing basis. As a result, decisions regarding space policy initiatives are frequently made ad hoc, with little regard to the Nation's long-term interests and posture in space. In its 1982 report, *Civilian Space Policy and Applications*, OTA explored various options for dealing with this absence of policy guidance, including reestablishing the National Space Council, establishing a Presidential commission on space, and "muddling through" with the status quo. In testimony before the House Committee on Science and Technology in August, 1982, OTA expressed reservations with regard to the focus and membership of the National Security Council's Senior Interagency Group (SIG), then recently established to provide guidance on space policy. These reservations remain. The matter of the appropriate form in which a new, effective, non-partisan, and broad-based professional group should be cast is being given focussed attention in OTA's *Civilian Space Stations* assessment.

(a) The American public clearly continues to have an interest in civilian space activities and a high regard for the professionals conducting them. But, since the extraordinary Apollo era, neither national opinion leaders nor the general public have felt themselves to be continuously and importantly concerned with the articulation of our national civilian space aspirations and activities. Defining the characteristics of our publicly-supported civilian space program has continued to be left to professionals who, over the past quarter century, have spent some \$200-billion (1983 adjusted) to learn how to study space, visit it, survive and function in it, and exploit it. These professionals, for the most part, are scientists, engineers, and research and development program managers in government, universities and the space industry. As a consequence, the character of the program essentially reflects the desires of relatively few of our 240 million citizens, i.e., those who are interested in space exploration and in scientific study in and from space, and the development of the advanced technology required to allow this exploration and scientific study to take place.

Thus, after the expenditures of a great public sum over the past quarter of a century, and with the acquisition thereby of great sophisticated space-related assets and experience, the character of the space activities of the United States still spring from a very restricted constituent interest in space. And this is the case even though, today, it is possible to imagine both a much broader participation in space activities by the general public, and much greater public, public-service, and economic benefits that could be provided by space investments and activities than is presently either the case or even the clear prospect.

In this circumstance it is unfortunate that, as we have found in our *Civilian Space Station Assessment* activities, except for a few ad hoc study efforts (such as the OTA assessment itself), and outside of the space sciences, there simply are no continuing, objective, professional studies being made in the United States of a national policy-related nature—studies that could be expected to articulate and prompt just such a broadening of our civilian space program prospects. (For instance, the great difficulty that the Congress has had in attempting to deal with the so-called "space commercialization" area in general, and the Landsat area specifically, is eloquent testimony to this fact.) For the most part, the Congress is informed on civilian space policy and program issues only by professionals, few of whom have useful experience in dealing with high-technology commercial-industrial matters, or any interest in so doing. And the information that it obtains from the "private sector" is, again for the most part, provided by those organizations already doing business with the government's space offices.

Therefore, the specific purpose (as our statement suggests) of initiating a "... broad and continuing study effort ..." in the civilian space area would be to provide the Congress and the American public with carefully considered innovative alternatives for the U.S. civilian space program. These alternatives would include goals, ob-

jectives, and policies, and they would be studied and presented in a continuing, objective, disinterested, and professional manner.

In essence, the expectation would be that such a study effort would support, most usefully, a "process" by which broad, informed debate re our nation's civilian space aspirations would be considered in a continuing fashion. And such a process, such a continuing debate, should help to publicize opportunities, and quicken and broaden interest in our nation's publicly-supported space program. In so doing, it would be of clear and direct assistance to the Congress.

(b) One possibility for increasing broad public participation in setting space goals and priorities would be to hold hearings at various locations around the country, and to encourage interested groups and individuals currently not belonging to any organized space communities to participate. Such hearings could be effective if witnesses were asked to comment upon alternative sets of civilian space goals.

In the longer run, the existence of one or more extra-governmental, independent advisory bodies on space policy would also contribute to increasing public awareness and subsequent participation in setting space goals and priorities as findings and recommendations were released. The OTA Civilian Space Stations assessment is paying particular attention to the appropriate institutional form such an advisory body could take, and we expect to be able to speak usefully to this issue early next spring.

Senator GORTON. Thank you.

Given the time, I think I will submit the balance of my questions to you in writing.

Thank you both very, very much. We appreciate it.

The meeting is adjourned.

[Whereupon, at 12:23 p.m., the subcommittee was recessed, subject to the call of the Chair.]

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

SALYUT—SOVIET STEPS TOWARD PERMANENT HUMAN PRESENCE IN SPACE

A TECHNICAL MEMORANDUM

INTRODUCTION

A number of citizens of the Soviet Union, and their guests from other countries, have visited the Earth's lower space regime; the Soviet in-orbit space infrastructure, primarily the Salyut space stations (or, as the Soviets say, "orbital stations"), has housed and supplies them there, more or less continuously, for over a dozen years. During this period the total number of hours that Soviet cosmonauts have spent in space has overtaken and is now much greater than the corresponding total for U.S. astronauts. By all accounts, the Soviets are more knowledgeable than the United States in space biology and medicine; in a number of technical areas, notably in the use of automated docking systems, they routinely use techniques that the United States has never demonstrated. It is true, on the other hand, that the Space Shuttle now gives the United States significant capabilities that the Soviets do not have, but it is widely believed on the basis of photographic evidence available from unclassified sources that the Soviet Union is developing both a small space plane and a heavy-lift shuttle expected to be capable of propelling more massive payloads into low-Earth orbit than can its U.S. counterpart.

The Soviet space station program is the cornerstone of an official policy which looks not only toward a permanent Soviet human presence in low-Earth orbit but also toward permanent Soviet settlement of their people on the Moon and Mars. The Soviets take quite seriously the possibility that large numbers of their citizens will one day live in space. Although the Soviets do not often directly communicate detailed results of what has been learned by and from the cosmonauts aboard Salyuts, enough information is available to conclude that they are accomplishing more than rudimentary scientific investigations: they are providing the data, information, and experience required to design habitats and equipment which will allow individuals to reside for the long-term in space.

The Soviet approach to the development of space capabilities differs significantly from the American. Whereas the United States tends to advance from one space capability to the next by quantum leaps, the Soviet Union tends to modify and adapt technology that is already in hand, thereby increasing its capability in a seemingly more evolutionary or progressive fashion. By thus relying on systems flight-proved in earlier space programs, the Soviets may have been able to restrain costs and minimize the time spent in development and construction. The Soviet space program and the U.S. satellite communications industry are similar in that both allow for the establishment of gradual evolving spacecraft design, and it may be advisable for the United States, in other selected areas of space applications, for example, to adopt some form of the Soviet strategy. Already, NASA's Solar System Exploration Committee (SSEC), emphasizing the importance of system heritability, had advocated a similar approach for planetary science.

The relative merits of automated and human capabilities for performing work in space or, more precisely, the criteria for establishing the optimal mix of the automated and the human presence for particular tasks, are the subjects of considerable debate in the United States. Although the amount of time in space that American astronauts have amassed is nontrivial, there is a certain degree of unreality about this debate because it cannot yet be grounded in extensive experience. The Soviet Union, on the other hand, can draw on a much greater fund of experience as they implement plans for integrating human and machine capabilities for work on future space stations.

Perhaps the most important point to be made here is that the United States and the Soviet Union have cast the issue of humans versus machines in different terms. U.S. space policy is to explore and study space and to use it for general human benefit—and, where appropriate, to involve human beings in actual spaceflight. In

addition, both the United States and the Soviet Union use their spaceflight programs involving people to enhance their national images. Soviet space policy, however, goes further; it includes the goal of learning how human beings may reside permanently in space, both as an end in itself and as a means of serving their national purposes. To date, the United States has not committed itself to permanent human occupancy of space as a national goal.

EXECUTIVE SUMMARY

The launching of Sputnik 1 initiated a space race that led to the landing of astronauts on the Moon: today the United States and the Soviet Union are well aware of their relative strengths and weaknesses in space activity. In most areas of space science and space applications—best exemplified, respectively, by the Voyager missions to Jupiter and Saturn, and the burgeoning satellite communications industry—the United States, through steady, long-term effort, seems to have gained a substantial lead over the Soviet Union.

In human spaceflight, the picture is less clear because the countries have taken quite different approaches. In some respects, the activities of the two countries in this arena have resembled the race between the tortoise and the hare: while the Soviet effort has featured apparently steady, incremental progression along well-defined lines of development, the United States has typically played catchup, using its strong technological capacity to produce space achievements of startling virtuosity. Continuing development on both sides has been fueled by a combination of political, economic, and military motives, in different order of importance at different times.

The divergent approaches of the two countries have led to two very different types of current human spaceflight capability. The Soviet Union has, since 1971, pursued a more-or-less continuous program of development of space stations in low-Earth orbit (LEO). With the sixth operational model of the Salyut series now flying, Soviet cosmonauts have logged over three times the U.S. total of crew-hours in space, and accumulated extensive experience in the conduct of flight operations, experimentation, and Earth observation in trips that last for months. However, they are currently restricted to the use of relatively small, expendable launch vehicles for crew transportation and resupply. The United States, on the other hand, has an operational space Shuttle which permits the routine ferrying of crews and large payloads into orbit for over a week, currently at the rate of some 5-6 flights per year. The Shuttle is reusable, its staytime in orbit could be increased, and the planned fleet of four Orbiters could provide staytime on the order of months per year. But an individual unmodified Orbiter does not provide a habitation combining large volume, high power, and long duration needed for many of the in-orbit research and development activities of interest, particularly to the life sciences and some in the private sector.

The National Aeronautics and Space Administration is now considering "the next logical step for its space program: the establishment of a potentially permanent human presence as part of an actually permanent LEO infrastructure, i.e., what NASA describes as a civilian space station. If the administration formally proposes to begin work on such infrastructure, then Congress may find that a detailed examination of the Soviet Human presence in space, the Salyut space stations, and their associated space vehicles, can provide a useful frame of reference.

Early in this century, Konstantin Tsiolkovsky, a Russian scientist and engineer, provided the theoretical underpinnings for the Soviet space program with his visionary writings about the use of orbiting stations as a springboard for exploring the cosmos. One can still find the influence of his theories in the statements of modern-day Soviet leaders.

But Soviet scientists and technicians have found that the road to realizing their dream is a long and difficult one. After initial successes with Sputnik and the early orbital flights of cosmonauts in the one-seat Vostok capsule, the Soviet space program began to feel the limitations of its technology. The 6-metric-ton (Tonne; one tonne = 2205 lbs) Voskhod flew only twice, Voskhod 1 with three crewmembers, Voskhod 2 with two. Two years later, in 1967, a new space vehicle debuted with Soyuz 1. Despite the death of the first Soyuz pilot in a crash landing, the Soyuz-class ship eventually became the principal means of putting cosmonauts into space. After 12 years of Soyuz operations, a new design, Soyuz T, made its inaugural flight in 1979.

In the late 1960's, the Soviets appeared to be intent on sending cosmonauts to the Moon, but, in view of the success of the U.S. effort to do so, they eventually settled for landing automated probes on the lunar surface. Subsequently, the focus of the Soviet manned space program shifted exclusively to the establishment of a strong

capability for near-Earth orbital operations, i.e., the development of space stations and associated space vehicles. When Soyuz 4 docked with its sister ship Soyuz 5 in January 1969, the Soviets called the resulting complex "the world's first space station," although the two craft had no connecting passageway between them. Salyut 1, which provided one continuous volume capable of supporting human habitation for time-periods of the order of months, went into orbit in 1971; the most recent of the series, Salyut 7, was launched in 1982 and remains operational today.

Some of the Salyut stations were apparently military in function; others seem to have been primarily civil. With Salyut 6 and 7, the distinction became blurred; it may be that the military no longer has a separate Salyut program. The Soviets have maintained total secrecy in military operations, but they have gradually become more open with their civilian programs, broadening the makeup of their crews to include members from Eastern Europe and other Soviet-bloc countries, France, and, soon, India. Although any joint U.S.-Soviet effort (e.g., the symbolic joining of the Apollo and Soyuz in orbit in 1975) currently seems unlikely, future Soviet missions will probably continue to be international to some degree.

The fact that the Soviet technological base remains relatively narrow seems to be closely coupled with the infrequency with which rapid innovation is achieved, both in Soviet industry generally and in the Soviet space program in particular. Although Soviet spacecraft designers rely heavily on automated control with cosmonauts as backups, crewmembers have, in many instances, assumed broader duties to make up for failures in automation. In any case, Salyut has afforded its crews of engineers and cosmonauts extensive experience in conducting operations in space. Precisely how this experience will be put to use in future operations is unclear.

Salyut may be the penultimate step leading to a permanent, large-scale human presence in space. Before that can be accomplished, the Soviets may have to achieve success in developing a heavy-lift launcher, similar to the U.S. Saturn V, which would allow for the construction of a second-generation station out of much larger modules. A vehicle along the lines of the U.S. space shuttle to provide routine access to a near-Earth station would also be desirable, and indeed Western sources believe that the Soviets may be developing a heavy-lift, reusable shuttle that could carry twice the payload of the American craft. In addition, the Soviets have already conducted tests for a 1-tonne prototype of a 10- to 20-tonne space plane.

With such spacecraft in their fleet, the Soviets would possess both a "space truck" and a light duty ferry vehicle to provide routine service to an expandable infrastructure in space. With this infrastructure as a hub of operations, extension of human activity to geostationary orbit, the Moon, and even Mars becomes technically feasible—indeed Soviet planners have frequently mentioned each of these as an objective. That previous U.S.S.R. efforts to reach Mars have met with failure may, in the near term, have militated against their initiating programs to send vehicles to the outer planets and deep space. But it is unlikely that the Soviets see these failures as anything more than temporary setbacks, especially in view of U.S. success in planetary exploration generally and their own success in the very difficult task of returning data from the surface of Venus—a feat that the United States has yet to match. Indeed, a Salyut space station may provide the core element of a future base necessary to ensure success of future trips to Mars.

CONCLUSION

In any characterization of the future of the Soviet space program, caution is the rule. Western forecasters during the past 5 years expected a more dynamic effort than the Soviets actually put forth. Still, the Soviets have shown considerable perseverance, and their predictions about even bigger space stations—capable of housing "large collectives" rather than small crews—should be taken seriously. Modularized space facilities—carrying equipment for astronomical, physical, and chemical experiments, and for technology development purposes, adopted for multidisciplinary programs for both civilian and military purposes—can be expected.⁶⁹ It is possible that useful and marketable products and services could be provided. Such stations, situated in various orbits, would be a straightforward extension of demonstrated Soviet capabilities. Eventually, these same facilities could involve international terms.

⁶⁹ Comments of Anatoly Skripko, Science and Technology Attaché to the Soviet Embassy in Washington, D.C., at a luncheon of the American Astronautical Society, Feb. 12, 1982. See also "Soviets Initiating Program on Modular Space Station," by Craig Covault, *AW&T*, July 20, 1981, p. 22; and "Soviets Move Toward Space Operations Center," James Oberg, *Aeronautics and Astronautics*, May 1982.

With a sufficient commitment of resources, the Soviets may be able to maintain a continued human presence in space through the use of heavy-lift launchers and/or expended use of currently available boosters. A shuttle-type vehicle would permit routine access to platforms in near-Earth orbit. A large Salyut complex could serve as a space transportation node or base camp.

As recently as late November 1983, the Soviet newspaper (Pravda) asserted that the main thrust of Soviet cosmonautics is "the creation of [sophisticated] orbital manned complexes, which can be improved during lengthy use and be reconstructed depending on the nature of the tasks being tackled."⁷⁰ The next step in the Soviet space program will apparently be "the transition from long-term orbital stations regularly visited by replacement crews to multi-team, permanently manned orbital complex."⁷¹

From a permanent foothold in near-Earth orbit, the next step might be an extension to geostationary orbit. Soviet scientists have argued that a series of orbital stations might one day stretch for hundreds of miles in a given orbit.⁷²

Salyut operations are one step in the Soviet drive toward mastery of space. It is quite conceivable that, by the end of the century, they could put cosmonauts on the Moon.⁷³

STATEMENT OF DAVID W. LIPPY, PRESIDENT, AND BRAD M. MESLIN, EXECUTIVE VICE
PRESIDENT, CENTER FOR SPACE POLICY, INC.

Mr. Chairman and Members of the Subcommittee: It is a distinct privilege to submit a statement before this committee. The Center for Space Policy, Inc., appreciates the opportunity to present our views on the question of whether the U.S. Government should support a space station.

For the past year, the Center for Space Policy, Inc., has provided a range of analytic and consulting services to members of both the aerospace and financial communities. Recently, the Center concluded an ambitious work for a major aerospace corporation which examined the economic benefits of space. In June, 1983, CSP completed a study for NASA which surveyed twenty financial institutions in New York and Boston. These included commercial and investment banks, venture capital firms, insurance companies, brokers and underwriters. The focus of the study was an assessment of their attitudes, concerns and recommendations regarding the financing of potential space commerce activities. In addition, the Centers has provided to its corporate clients analysis of aspects of the proposed Space Station program, evaluations of new commercial market opportunities in space-related industries, and assessments of political and regulatory issues affecting commercial involvement in space.

Today, we will draw on this experience in an attempt to evaluate, in a broad sense, the necessity of a permanent space station. We feel the other witnesses have adequately addressed the utility and design issues pertinent to these hearings, as well as many of the most salient policy considerations. Instead, this testimony will concentrate, on the effect that a space station will have on the private sector perspective regarding government support for space commerce.

CSP's analysis of the current and potential economic benefits of the space program bears out the contention that significant opportunities exist for commercial space activities. In the area of space manufacturing, products with industrial applications range from biological and pharmaceutical materials to advanced metal

⁷⁰ Quotation from Pravda, Nov. 25, 1983, appearing in *Aerospace Daily*, Dec. 1, 1983, p. 155.

⁷¹ Pravda, Nov. 28, 1983, quoted in *Aerospace Daily*, Dec. 1, 1983, p. 155. The article continued as follows: "Pravda said the size of such a complex 'will be impressive even by the standards of construction on Earth. For instance, the parabolic antenna alone should have an effective aperture . . . [o]n the order of 300-350 meters. In addition, it must be geared to a long period of operation—15-20 years as a minimum.'"

"Pravda said that '[t]oday, this complex is conceived as a unified system of large-scale installations in orbit at an altitude of 200-400 kilometers, linked to Earth by freight and passenger transport spacecraft. The complex will include specialized scientific research laboratories, comfortable housing modules, powerful energy installations, a refueling station, repair workshops, and even construction sites for producing and installing standardized construction components. The real potential of orbital flight for the *ad hoc* solution of urgent national economic tasks will also be expended many times over.'"

⁷² Yuri Zaitsev, "Orbital Stations—The Present and Future," *Moscow News*, #45 (2825), Nov. 19-26, 1978, p. 11.

⁷³ The Soviets think that in about 20 years a journey to Mars may be possible. By this time, spaceships may incorporate centrifuges that simulate the conditions of living under gravity." Smolders, *op. cit.*, p. 944.

alloys and electronics materials. The development of a manned orbiting laboratory and processing facility would encourage private firms to explore the opportunities such a facility would offer. Provision of space services (such as satellite repair and other operations in low-earth orbit) offer a commensurate level of commercial opportunity. However, most companies and investors are reluctant to become involved without a tangible government commitment to the commercialization of space.

Private sector investment is based upon the estimation of profitability. Evaluation of profitability requires that the environment possess a degree of predictability such that risk can be assessed in advance. Interviews of financial managers conducted as part of the NASA study revealed several general characteristics regarding investment in commercial space ventures. The most common was that the financing of any space venture will ultimately depend on the merits of its proposal; and proposals will be assessed using many of the same macro-economic criteria used in judging any potential investment.

Investors perceive the excitement surrounding space commercialization as hyperbole for two reasons. First, there is a general lack of knowledge in the financial community regarding specific commercial opportunities in space. Second, investors are wary of becoming involved in projects that depend on a rate of return over a long period of time when little tangible evidence exists of a stable and durable government commitment to support such risk-prone ventures. CSP research suggests that the predictability of space ventures must be enhanced before they can be appealing to entrepreneurs and financiers. This can be accomplished through government provision of a space infrastructure and promotion of an enduring space policy.

Historical experience shows that trade follows the flag. America's commercial involvement in space will illustrate the same pattern if it is given the necessary support. Until the Federal Government makes a firm commitment to the basic infrastructural facilities needed to precipitate market-oriented research and development by the private sector, investors will remain unresponsive to commercial space investment opportunities. A Government-funded "railroad" (i.e. the Shuttle) with no destination is an insufficient incentive for frequently conservative institutional investors to expend funds. A forward-looking and consistent national space policy must include the establishment of space facilities that the investment community is either unable or unwilling to support, itself.

Investor confidence is a key factor in turning potential space ventures into profit. The high costs associated with most major space projects require the resources of capital markets. According to financial managers, the first thing that must happen if these funding requirements are to be met is formulation of a stable government policy that would cover a span of at least ten years and be relatively immune from change that might result from changes in Congress or in the Administration. NASA projects that a space station program beginning in fiscal year 1985 would have an initial operational capability sometime in the early 1990's. This is precisely the kind of policy initiative that will lend credence to space entrepreneurs when soliciting funds for space ventures. It sends a signal to the investment community that the Government means business. This alleviates investor fears that committed dollars are being held in a precarious state.

President Reagan has met with aerospace industry executives on two occasions to hear their views on space commercialization. The feedback the President has received includes support of a space station program in order to facilitate stable commercial growth in space. A space station would demonstrate to industry representatives that the government is serious in its intentions to open space to the private sector without impeding its progress in future years or future administrations.

Internationally, the Europeans and the Japanese have each targeted specific space technologies for development and could soon be providing U.S. corporations with stiff competition. The direction of the U.S. space program must be dealt with in an expeditious manner in order to forestall damaging consequences for the U.S. balance of trade in an increasingly competitive global economy. Increased foreign activities in this area threaten the loss of significant revenues for U.S. firms, as well as U.S. prestige and technological preeminence.

Successful European and Japanese programs are products of industry-government partnerships which the United States must examine. As a means of encouraging similar activity, NASA has established a number of different mechanisms to foster productive relations with industry. However, these initiatives do not approach the level of tangible commitment reflected in the institutional arrangements of other nations. Such supporting investments by the Government could occur in such areas as: technology procurement and operation of materials testing facilities and support; unmanned space platforms; the establishment of commercially-oriented data bases

for the dissemination of scientific and non-scientific information; and, a Space station, to name but a few.

A Space Station would catalyze significant interest and activity in many areas. Without a space station, a few Shuttle-based experiments and a limited space services infrastructure will stand as noteworthy examples of what could be accomplished, instead of concrete steps toward the development of burgeoning space industries. Approval of a Space Station program in the context of a broader national space initiative will underline this nation's dedication to a vigorous, forward-looking national priority, one that will garner economic, social, and political benefits for the United States far outweighing the Government's financial investment.

Thank you for the opportunity to submit this statement.

